RESEARCHES
PRACTICAL AND PHYSIOLOGICAL
ON
ETHERIZATION

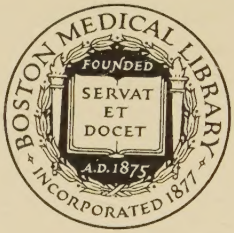
BY

N. PIROGOFF

English Translation by
B. RAYMOND FINK
From the French Original

WO
200.3
P671r
1992

BOSTON
MEDICAL LIBRARY



IN THE
Francis A. Countway
Library of Medicine
BOSTON

Gift of

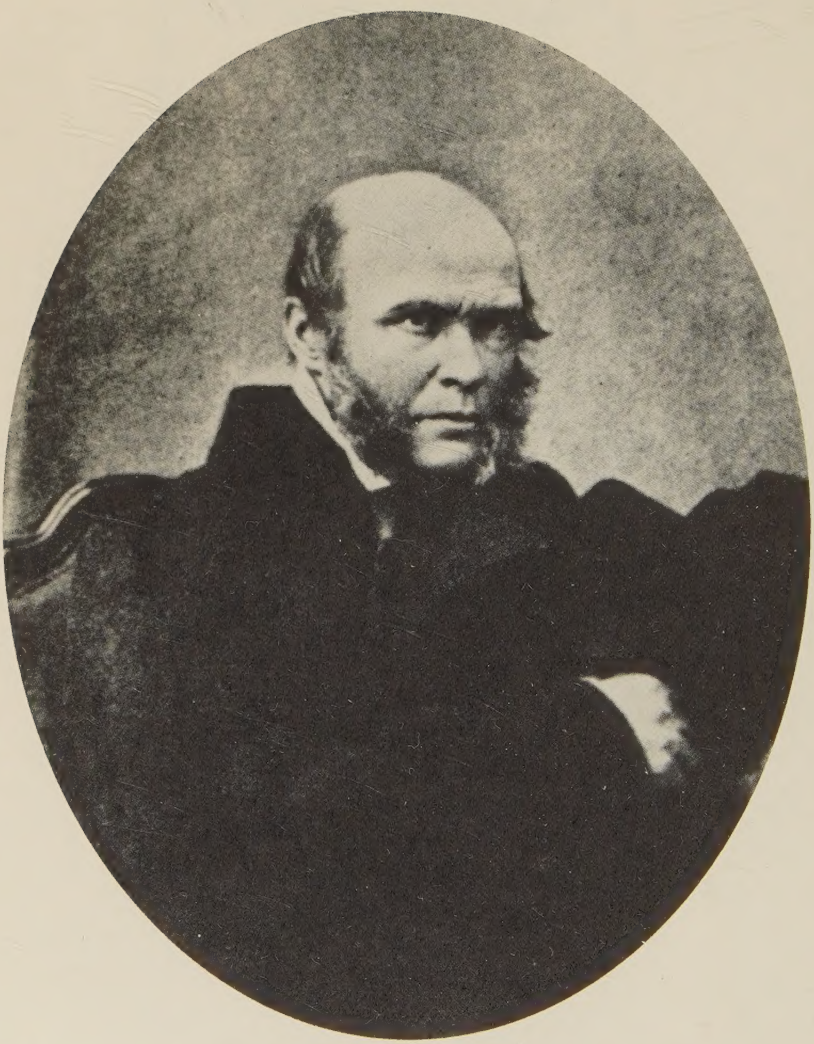
New England Journal of Medicine

RESEARCHES

PRACTICAL AND PHYSIOLOGICAL

on

ETHERIZATION



Nikolai Ivanovich Pirogoff

RESEARCHES

PRACTICAL AND PHYSIOLOGICAL

on

ETHERIZATION

by

N. PIROGOFF

Doctor of Medicine; Academician; Professor at the Medical and Surgical Academy of St. Petersburg; Surgeon-in- Chief, Second Military Hospital; Head of Anatomical Studies; Consulting Surgeon, Oboukhow, St Mary-Magdalene, and St. Peter and St. Paul Hospitals; Councillor of State; Member of the Medical Council and Corresponding Member of the Academy of Sciences.

English Translation by
B. RAYMOND FINK
From the French Original

WOOD LIBRARY MUSEUM
OF ANESTHESIOLOGY
Park Ridge, Illinois

00
00.3
671r
992
opy 1

Copyright © 1992 Wood Library-Museum of Anesthesiology

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, mechanical or electronic including recording, photocopy, or any information storage and retrieval system, without permission in writing from the publisher.

Library of Congress Catalog Card Number 91-68475

ISBN 0-9614932-3-2

Printed in the United States of America

Published by

THE WOOD LIBRARY-MUSEUM
OF ANESTHESIOLOGY
515 Busse Highway
Park Ridge, Illinois 60068

RECHERCHES

PRATIQUES ET PHYSIOLOGIQUES

SUR

L'ÉTHÉRISATION

PAR

N. PIROGOFF

Docteur en Médecine; Académicien; Professeur à l'Académie Médico-Chirurgicale de St.-Pétersbourg; Chirurgien en chef du second Hôpital militaire; Chef des travaux anatomiques; Chirurgien consultant aux hôpitaux d'Oboukhow, de St. Marie-Madeleine et de St. Pierre et St. Paul; Conseiller d'État, Membre du Conseil Médical et Membre Correspondant de l'Académie des Sciences.

ST. PÉTERSBOURG.

Imprimerie française. Troïtzky péréoulok. № 3.

1847.

Published by

THE WOOD LIBRARY-MUSEUM

an affiliate of

THE AMERICAN SOCIETY OF ANESTHESIOLOGISTS, INC.

Park Ridge, Illinois

1992

CONTENTS

TRANSLATOR'S PREFACE ix

BIOGRAPHICAL NOTE: xiii
NIKOLAI IVANOVITCH PIROGOFF
by O. Secher, with references xiii-xxvii

RESEARCHES ON ETHERIZATION
INTRODUCTORY DISCUSSION 1

I. EXPERIMENTS
ETHER APPLIED TO NERVOUS TISSUE 31
II. EXPERIMENTS
ETHER INJECTED INTO THE BLOOD 35
III. EXPERIMENTS
ETHER INTRODUCED INTO THE TRACHEA 39
IV. EXPERIMENTS
ETHER INTRODUCED VIA THE RECTUM 43

DISCUSSION 48

METHOD OF ETHERIZATION
VIA THE RECTUM 60

EXPLANATION OF FIGURES 75

Digitized by the Internet Archive
in 2025

https://archive.org/details/researchespracti0000piro

TRANSLATOR'S PREFACE

The advent of anesthesia in 1846 heralded a new age of pharmacology and physiology, a new birth of surgery and medical science. No less than fifteen books on ether anesthesia were listed as published in 1847 in the Surgeon-General's Index Catalogue of 1883. For the most part these presented the experiences of pioneering surgeons, but three monographs, respectively from Russia, Germany, and Great Britain, attested the intense intellectual struggle to master and understand the great discovery. Of the three, the one by Nikolai Ivanovitch Pirogoff, although unaccountably missing from the Surgeon-General's list, was actually first off the press. Next came von Bibra and Harless's brilliant but misguided effort to establish a postulated chemical mechanism of anesthesia, and, last, John Snow's classic *On the Inhalation of the Vapour of Ether*.

Several persons conceived the notion of rectal administration of ether independently and at about the same time (clysters were still quite popular — in some quarters these had earlier been charged with orange petals or rose blossoms, supposedly to preserve the freshness of the recipient's complexion). Pirogoff received little immediate notice, and

the fact that he wrote in French may help to account for his lack of recognition in English-speaking circles. Yet among the early experimental and clinical studies of ether anesthesia Pirogoff's is surely one of the best. His was incontestably the most extensive and best documented of the initial investigations of ether anesthesia induced *per rectum.*

Pirogoff's true stature emerges in the biographical essay included with this translation by kind permission of its author, Professor Ole Secher, and the editor of *Anaesthesia.* Pirogoff became professor of surgery at the University of Dorpat at the age of twenty-six (he received a medical degree when only seventeen years old) and wrote in his first annual report:

"I have decided to make it a rule upon assuming the chair of surgery never to conceal from my students errors made by me, whether in diagnosis or in the treatment of disease. . . . I consider it my sacred obligation as a cautious teacher immediately to publicize my errors and their consequences so as to warn others against making the same mistakes." And again, "My most ardent desire is that my pupils should treat me critically." At the end of his first lecture, Pirogoff addressed his students as follows: "Gentlemen, you, of course, realize that my German is bad and that is why I cannot be as explicit as I would like to be. Therefore I would beg you to let me know after each lecture just where I was obscure." One of his students wrote subsequently: "It was quite remarkable that a man who was met with distrust and almost hatred should become a few weeks later the most respected and loved of the professors."

In the present book Pirogoff begins with a fascinating account of the objections to anesthesia which the trained surgical mind of the day was apt to raise. He goes on to evaluate his clinical experience with ether anesthesia administered by inhalation, giving many graphic details and noting among other things that etherization as such does not affect the process of wound healing, a matter of great con-

cern to a surgeon. He proceeds to describe 45 experiments on animals with ether administered by almost every conceivable route: direct application to nerve, direct application to the brain, introduction by vein, by artery, by inhalation, and, finally, by rectum. He presents a classification of ether anesthesia into four degrees and follows this with speculations on the mechanism of ether anesthesia. This part of his discussion is worthy of careful attention even today, because it represents a determined attempt by an educated mind to analyse the observed phenomena in terms of purely physical and chemical molecular mechanisms, constrained by the severe limitations of the understanding then available. He inclined to the idea that ether anesthesia is due to a mechanical action of the vapor on nerve fibers.

Pirogoff goes on to describe and illustrate his apparatus for rectal administration, reports on 50 cases, including 10 failures, and concludes with a discussion of the principal advantages of this route. His claims were not overstated. One hundred years later, drug administered *per rectum* was still the method of choice for 'stealing' the induction of thyrotoxic patients in bed before they were taken to the operating room to undergo subtotal thyroidectomy.

During the Crimean War Pirogoff and Grand Duchess Helène Pavlova organized the Russian army nursing service, starting about one year before a similar enterprise was begun by Miss Florence Nightingale on the British side. This far-reaching initiative might be compared with that of John Snow in stemming the water-borne spread of cholera by removing the handle of the Broad Street pump.

Pirogoff's systematic approach to anesthetic research and his resourcefulness and objectivity as an observer are reason enough for agreeing with Professor Secher that Pirogoff is entitled to a greater place in the history of anesthesia than he has hitherto enjoyed.

— B. Raymond Fink,
Seattle, 1991

BIOGRAPHICAL NOTE*

NIKOLAI IVANOVITCH PIROGOFF

by O. Secher
Professor, Department of Anaesthesia
University of Copenhagen, Denmark

The name of Nikolai Ivanovich Pirogoff (Pirogov), 1810-1881, is well known in the history of anaesthesia and is mainly connected with the rectal administration of ether vapour. Rarely mentioned, however, is his book[1] on the use of ether entitled *Recherches pratiques et physiologiques sur l'éthérisation*, published in St. Petersburg in 1847, and which was one of the first on the subject.

Before Pirogoff published his book, at the end of May or early June 1847, (it was approved by the censor on the 17th of May 1847) a short message which he sent to the Académie des Sciences in Paris, was presented at its meet-

*Reprinted from Anaesthesia, 1986; 41:829-837, by permission.

ing on 5 May 1847. This was entitled *Nouveau procédé pour produire, au moyen de la vapeur d'éther, l'insensibilité chez les individus soumis à des opérations chirurgicales*.[2] After having experimented with dogs he had used rectal administration of ether vapour on patients with good results.[3-5] On 16 March, 1847, Marc Dupuy, an interne des hôpitaux at the Hôtel-Dieu in Paris, had presented a similar paper at the Académie de Médecine, but no abstract of this paper exists. Three weeks later, Dupuy presented his results to the Académie des Sciences: *Note sur les effets de l'injection de l'éther dans le rectum*. He had experimented with three dogs and a rabbit and injected a mixture of 15 g ether and 15 g water into the rectum. He found his results better than with ether administered by inhalation.[4-6] The same year, Marc Dupuy may have published a book: *De l'éthérisation* but this has not been seen by the author of the present article.

Shortly after the appearance of his book, Pirogoff sent a copy to the Académie, together with another message which was read to the Académie at the meeting on the 21st of June. *Effets des vapeurs d'éther par le rectum*. In this he mentioned that he had used 'his method' on seven more patients. This presentation has been published.[4,5,7] In his comments on this presentation, W. Stanley Sykes (1894-1961) states: "Here, as in the case of Velpeau (Louis Velpeau, 1795-1867, Charité, Paris) we can trace the beginning of the continental attitude to anaesthesia. If things do not work perfectly the first time, do not bother to learn how to do it. There is not anything to learn. Try something else."[5] This is not a fair statement, and can only be due to the fact that Sykes had not read Pirogoff's book. Sykes also states that Pirogoff first gave rectal ether on 2 April, 1847, but I have not been able to confirm this. Pirogoff was convinced that he had found a better method for the administration of ether, which gave less trouble to the patient and the surgeon.

Although Pirogoff must be considered the first to have administered ether *per rectum* to patients, neither he nor Dupuy were the first to experiment with the method. J. Vincente y Hédo in Madrid had tried it on animals, but considered it too dangerous.[8,9] Also, the Austrian veterinarian, H. Seifert, had used it and gave a demonstration of it on horses, cows, sheep and dogs on 6 February 1847.[8] In his book Pirogoff mentions only one name, Magendie (François Magendie, 1783-1855) who had performed experiments on animals using rectal ether, but clinicians had paid no attention to it. Perhaps it was Magendie who gave Pirogoff the idea.

Education and Career

It is pertinent to record briefly the life and accomplishments of Nikolai Ivanovich Pirogoff. He was born in Moscow on 13 November 1810, the son of a treasurer and he had his first schooling and first medical education there. He graduated from the University in 1827 at the age of 16 years. The same year he was selected as a crown stipendiary and sent to the University in Dorpat for further training. Here the education was better, and the students were selected likely candidates for the future position of professor. He graduated in 1832 and defended his thesis the same year: *Num vinctura aortae abdominalis in aneurysmate inguinali adhibita facile ac tutum sit remedium*? (Is the ligation of the abdominal aorta in inguinal aneurysm an easy and safe procedure?).

The University of Dorpat was founded in 1626 by the Swedes under King Gustav II Adolf (1594-1611-1632), and named Academia Gustavianum, as Estonia at that time was a Swedish area. The university got the same privileges as the university in Uppsala, founded in 1477. It functioned until 1656 when the Russians conquered the city, but was

reestablished in 1690 under King Carl XI (1655-1660-1697) and given the name Academia Gustavo-Carolina. In 1699 it was moved to Pernau (Pärnu), as the Russians once more conquered the city. During the war between King Carl XII (1682-1697-1718) and Emperor Peter the Great (1672-1682-1725) Sweden lost Estonia in 1710 and the university was closed.[10] In 1802 it was re-opened by the Russians under Emperor Alexander (1777-1801-1825) in Dorpat (Tartu), this time with a heavy German influence, and it still exists. In the same period, the Swedes also founded a university in Åbo (Turku) in 1640 and in Lund in 1666. They had taken over the university in Greifwald, founded in 1456, when Pommern belonged to Sweden, from 1630 to 1720.

During his studies in Dorpat, Pirogoff concentrated on anatomy and surgery, two subjects which were to be his main interest in the following years. In 1833 the crown stipendiaries were sent to Germany for two years for further education. Pirogoff decided to go to Berlin via Copenhagen and Hamburg. He went to Copenhagen by ship from Riga and this was the first city he visited outside Russia. Here he visited hospitals and was well-received by the surgeons, except for one, who refused to allow him to observe his operations. The surgeon was a well known cystoscopist, Ludwig Lewin Jacobson (1783-1843), who had invented a cystoscope for stone crushing. Unfortunately, Pirogoff does not write very much more about his visit.[11]

He studied surgery for two years in Berlin and Göttingen and returned to Russia in 1835. The following year, Pirogoff became professor of surgery at the Dorpat University until he moved to St. Petersburg in 1841. His wish had been to become professor in Moscow. Apart from visiting Paris and Germany in 1837-38, he devoted his time at Dorpat to surgery, anatomical studies and teaching. During this period he wrote a number of articles and two monographs: *Über die Durchschneidung der Achilles-Sehne als*

operativorthopädisches Hilfmittel, Dorpat 1840 (About the cutting of the Achilles tendon as an operative orthopaedic help) and *Chirurgische Anatomie der Arterien und der Fascien*, Dorpat 1840 (Surgical anatomy of the arteries and fasciae).

Shortly after his promotion to professor at the Military Medico-Surgical Academy in St Petersburg, he married a daughter of count Dimitri Berjosin, and the year after they had a son and two years later another. Shortly after the last delivery, his wife died of a meningitis. Later he remarried, before the Crimean War. His oldest son, Nicolaj Nicolajewitsch Pirogoff (1843-91) became a well-known physicist.

Pirogoff's stay in St. Petersburg lasted until 1860, and here he made considerable improvements in the hospital, organised operations and continued his anatomical and surgical studies. When the Danish doctor Peter Plum (1829-1915), later professor of surgery, visited the hospital in 1866-67, he gave a very favourable description of it, but he never met Pirogoff, who had retired by that time.[12]

Pirogoff's anatomical studies, which he started in Dorpat, finished with the issue of a great atlas in 1849: *Anatomia topographica sectionibus per corpus humanum congelatum triplici directione ductus illustrata.* This consisted of four volumes with 224 drawings of topographical anatomy of sections in three directions through the frozen human body. He published a further book *Chirurgische Anatomie der Arteriestamme etc.* in 1860.

Researches In Anaesthesia

He started his investigations on ether early in 1847 and first gave ether by inhalation to a patient on the 14 February.[13] He must have started his animal experiments shortly after. In his book: *Recherches pratiques et physiologiques*

*sur l'éthérisation,** he described his experience of administering ether to 50 patients and 40 volunteers. Initially, he used a primitive apparatus, a bottle with a tube to the nose and a Charrière apparatus (Joseph Frédéric Benoit Charrière, a Paris instrument maker).[14] Pirogoff was not satisfied with this apparatus, as the mask was too small and the resistance too high, so he constructed an apparatus of his own for ether inhalation.

He summarised his experiences in the following statements:

> Even if the inhalation of ether is indicated in all important and painful operations, its action on muscle-function cannot be predicted. A pre-anaesthetic test cannot alone predict this, but will make the patient more confident; for operations that are delicate rather than painful, ether should not be used because of excitation, convulsions and automatic movements; in eye operations it can make circumstances easier as well as more cumbersome; it should not be used for operations in the mouth and pharynx; for stone crushing it is as useful as for other operations; removing stones through loin or perineum is much easier due to muscle relaxation. In deliveries, rupture of the perineum is avoidable. However, it can provoke urinary bladder spasms; above all etherisation is useful for incarcerated hernias, dislocations and ankyloses, because of its relaxing effect on the muscles; experience shows that ether inhalation should never be used on patients with dispositions for haemoptysis and headaches; for therapeutic purposes, ether can be mixed with other substances which are soluble in ether.

The next part of the book is an account of his experiments, mainly on dogs. He started by applying ether directly to peripheral nerves, the medulla and brain, while stimulating the areas mechanically and electrically. In an-

---

*Professor Elena Damir, Moscow, has informed me that only one copy of this book exists in Russia, namely at the library of Leningrad, where it is safely locked up.

other series, he administered ether intravenously and intra-arterially and thereafter stimulated peripheral nerves. In some of the experiments he gave ether as a vapour. For arterial injection he used carotid and crural arteries. In single experiments ether was given into the portal vein and the stomach.

In the third series, ether was given transtracheally, and the 'pneumogastric' nerve was cut, after which the effects of stimulation of the peripheral nerves was examined. In a couple of experiments the effect of ether was compared with ammonia, and also the effect of strychnine on the medulla was tested. One dog had a Caesarean section with the aid of ether, but the four puppies died.

The fourth group of experiments concerned the rectal administration of ether vapour. In a couple of experiments the rectum was ligated before the administration, and in a single case the thorax was opened and the irritability of the heart examined. Shortly after the rectal administration it was possible to smell ether in the expired air.

To obtain anaesthesia two conditions had to be fulfilled: ether had to be absorbed in the blood mass and there had to be contact between the blood and the nervous system. After these experiments he gave a long explanation of the results obtained. If liquid ether is injected into a vein, death occurs immediately, even if the vein is not close to the heart. The same result is obtained if it is injected into the carotid artery. The first case he likened to an air embolism; the second case, he suggested, was similar to increased intracranial pressure. Animals can be anaesthetised by careful injection of ether vapour, but if it is mixed with air the animal will die.

Signs of anaesthesia are only seen when etherised blood has passed the lungs. The smell of ether in the expired air is therefore an important sign of sleep and loss of pain sensation and indicates that ether has passed from the lungs

into the arterial blood. Rectal administration of ether results in rapid absorption due to the large surface. He concluded that ether had a limited local action on nerves and when applied directly to the brain, anaesthesia was not efficient until it could be smelled in the expired air. This meant that ether had passed into the blood through open veins, dura mater and brain nerves.

After this Pirogoff established four degrees of anaesthesia:

1st degree: as long as ether is present only in venous blood, or as long as the arterial blood is not sufficiently saturated with ether, etherisation only influences the circulation and the respiratory organs;

2nd degree: here the brain is affected, but not the medulla motor or sensory fibres;

3rd degree: this is a higher degree of influence on the medulla, reflexes disappear, mechanical stimulation of the nerves has no effect, but galvanic stimulation still works and can produce convulsions;

4th degree: no sensation or movements and total relaxation. Irritation of medulla has no or reduced action and only the heart is beating.

In the last part of the book he gives instruction on the rectal administration of ether and a description of his apparatus. He regarded this method as superior to inhalation as there was no excitement, anaesthesia was induced rapidly following removal of the apparatus and muscle relaxation was better. Other advantages he claimed were that the respiratory organs were not affected, the method was independent of the patient's will, there was no excitation, so that the patient appeared to be in a deep sleep; which was important during serious and delicate operations, and it lasted longer.

Following this, Pirogoff went on to describe his experiences with operations on 50 patients using ether anaesthesia. In six or seven, etherisation by inhalation was not successful, either due to defects in the apparatus or because the patients had had too little ether before the operation started. Using rectal ether in 40 cases, one was unsuccessful because the rectum was full, in another the construction of the flexible tube from the vaporisation chamber was faulty, while in a third the rectum was too irritable. Two patients died due to renal disease. He noted that the fever reaction was limited, especially after amputations, herniotomies and removal of large tumours. He stated that it was too early to give an opinion of 'my method' because it had been used on an insufficient number of cases and also that one day it could be expected that the use of ether either through the lungs, rectum or skin would have a beneficial effect on internal and external diseases.

He concluded that because of the advantages of his method of rectal ether, it was to be preferred in the following cases: all delicate, painful and long lasting operations; all obstetrical operations; operations which need muscle relaxation, reposition of incarcerated hernias and dislocations; spasmodic diseases in guts and urinary organs and spastic diseases in voluntary muscles. Because of the perfect muscle relaxation, which is seen following rectal administration, this method is suggested in these cases.

Shortly after Pirogoff finished his book, he had a chance to use ether for anaesthesia under war conditions. In the beginning of spring 1847, mountain tribes in the Caucasus area rebelled against the Russian government, and in the beginning of June, Pirogoff was ordered to travel to the war area. He arrived in Piatigorsk at the end of June, where he treated the first wounded. For anaesthesia he had brought with him a number of his anaesthesia masks.[13] Being a director of a factory manufacturing surgical equipment, this

must have been easy. The journey continued via Taurdshidakh, and after passing a number of places he came to the frontier at the town of Salty. Two months after his arrival the war was over, and in October he started travelling back.

This must have been the first war in which anaesthesia was used in a great amount. It was also used in the American-Mexican war of 1846-48, but information about this is scarce.[15] In his book: *Rapport médical d'un voyage au Caucase*, (St Petersburg, 1849) which was accepted by the censor 14 May 1849, Pirogoff has a long chapter on the use of ether under war conditions, the indications for its use and the experiences he gained. In all, he anaesthetised 100 wounded, of whom only two had rectal ether. The primitive conditions and open fire prevented its use. A number of operations were performed on the battlefield and rectal ether was administrated by one person, who was kneeling between the patient's legs while another, half sitting, held the patient from behind.

Before the [second] book was published, chloroform had been introduced, and Pirogoff was the first to use it in Russia on 30 November 1847 in St Petersburg.[13] Therefore, the book contains a comparison between the use of ether and chloroform. In a long list, divided into all kinds of operations, he has collected information on all the anaesthetics, both ether and chloroform, given in Russia in the period from February 1847 to February 1848. There were a total of 690 anaesthetics, out of which 208 were with chloroform, given within 3 months. Experiences from the war are also described. Chloroform was thought to be superior mainly due to the simplicity of administration and its rapid effect. In those days, speed was a sign of a good surgeon. In this book he tried to evaluate the influence of anaesthesia on the results of the surgery. It is not possible directly to relate the use of anaesthesia on surgical out-

come. In a table which included 231 anaesthetics given for low risk operations, there were three deaths, one each for ether, chloroform and rectal ether. Two of these deaths were probably due to anaesthesia.

Pirogoff's conclusion was that anaesthesia probably had no influence on the surgical results. He was probably the first to make some statistical attempt at studying the outcome of surgery under ether anaesthesia.

When he returned to St Petersbuurg, he worked on a surgical book: *Klinische Chirurgie. Ein Samlung von Monographien*, published in Leipzig in 1854. The Crimean War started in March 1854 and in October of that year Pirogoff was ordered to Sevastopol where he stayed until the war was over in February 1856. During this period, he showed himself to be an excellent organiser of the ambulance service and he introduced an effective triage of the wounded after a careful surgical examination. The wounded were carefully transported and plaster bandages were used; the infected patients were isolated. In cooperation with Grand Duchess Helene Pavlova, he organised a women's corps to nurse the wounded about a year before Florence Nightingale (1820-1910) started her activities in Scutari. Chloroform was mainly used for anaesthesia; Pirogoff wanted to use this for all cases. The Russians performed about 10,000 operations during the war.

Pirogoff's experiences from the two wars were published in the book: *Grundzüge der allgemeine Kriegschirurgie. Nach Reminiszenzen aus den Kriegen in Krim und in Kaukasus und aus der Hospital Praxis*, Leipzig 1864).

Due to disagreements with hospital and university administrations, Pirogoff retired from his position at the Academy in 1860 and became curator, first of the University of Odessa, and later of the University of Kiev. He stopped his practical surgical activity in 1866. His new positions required some travelling as he had control of students study-

ing medicine in German. Around 1863 he stayed one year in Germany.

During the French-German war, 1870-71, Pirogoff was sent as an observer to French and German hospitals. Here he observed with satisfaction that the principles from his book were in practical use. What he observed was written in another book: *Bericht über die Besichtigung der Militär-Sanitätsanstalten in Deutschland, Lothringen und Elsass im Jahre 1870* (Leipzig 1871). He was an observer in the Russian-Turkish wars in 1877 and 1878, and wrote another book entitled *Army medical service and volunteer aid at the theatre of the war in Bulgaria and in the rear of the armies in the field in 1877-78* (St Petersburg 1879). This book was only printed in Russian.

When Pirogoff was in Kiev, he bought an estate, which he later changed for an estate at Wishnja, 200 km southwest of Kiev. Here he lived when he retired as curator in 1866, and he then developed an interest in farming. He became justice of peace, an office which included taxation of farms and houses, and he was also interested in public and school education.

Pirogoff's 70th birthday was celebrated in Moscow, where he was elected an honorary citizen. Shortly afterwards he became ill with throat symptoms. Professor Theodor Billroth (1829-94) the famous surgeon in Vienna, was consulted, and he claimed the disease was innocent. Some time later, on the 25 November 1881 Pirogoff died from a cancer of the larynx. Later on Billroth declared that he was well aware of the disease, but had abstained from surgery due to the patient's age and physical condition. Billroth had performed the first laryngectomy in 1874.

Pirogoff's Place in History

In the history of anaesthesia the name of Pirogoff is well known, mainly in connexion with the rectal adminis-

tration of ether, but he ought to have a greater place. He was one of the first to perform systematic experiments with ether, he divided the anaesthetic state into four degrees, which were rather similar to the degrees found by Pierre Jean Marie Flourens (1794-1867) of Paris, in his experiments in February-March 1847.[14] Pirogoff tried ether under war conditions very early on and in more cases than most others. He produced his own equipment for inhalation and rectal administration and he was one of the first to try statistical analysis of the influence of anaesthesia on the operative results. Within surgery his name is well-known in connexion with the operation he described, an amputation of the foot without making the leg shorter, and the anatomists knew him for his atlas.

Pirogoff's method of rectal administration of ether was revived in Copenhagen by the surgeon Oskar Wanscher (1846-1906) in 1884[16] and the same year adopted in Lyon by Daniel Mollière (1848-90).[8,14] He had been visited by a Danish surgeon Axel Iversen (1844-92) (in most articles about the subject his name is spelled Yverson), who made him try the method.

It was also in use in the United States at that time. Again, in 1905, the method was tried in Boston by John Henry Cunningham (1877-1969) and Frank Howard Lahey (1880-1953)[4,17] and in England by Dudley Wilmot Buxton (1855-1931) of London, described in his book: *Anaesthetics: their use and administration*, in the 1907 edition.[8,9] Around 1910-14 both W.S. Sutton[9] and John Taylor Gwathmey (1863-1944)[18] modified and used the method. In Denmark the method was again in use in the twenties and thirties[19] and in England rectal oil-ether was used for plastic surgery round 1920.[20] The history of rectal administration of ether has been the subject of two reviews.[8,9]

References

1. Keys TE. *The history of surgical anesthesia.* New York: Schuman, 1945.
2. Pirogoff NJ. Nouveau procédé pour produire, au moyen de la vapeur d'éther, l'insensibilité chez les individus soumis a des opérations chirurgicales. *Comptes Rendus de l'Académie des Sciences* 1847; *24*:789-91.
3. Cole F. *Milestones in anesthesia.* University of Nebraska Press, 1965:77-8.
4. Faulconer A, Keys TE. Rectal Anesthesia. *Foundations of anesthesiology*, Vol. II. Springfield, Illinois, USA; Charles C. Thomas, 1965:719-55.
5. Sykes WS. An intestinal interlude. *Essays on the first hundred years of anaesthesia*, Vol. II. London: E and S Livingstone, 1961:161-7.
6. Dupuy M. Note sur les effets de l'injection de l'éther dans le rectum. *Comptes Rendus de l'Académie des Sciences* 1847; *24*:605-7.
7. Pirogoff NJ. Effets des vapeurs d'éther administrées par le rectum. *Comptes Rendus de l'Académie des Sciences* 1847 *24*:1110.
8. Livingstone HM. Rectal anesthesia. In: Hale DE, ed. *Anesthesiology by forty American authors.* Philadelphia, USA: FA Davis Co., 1955:363-77.
9. Sutton WS. Anesthesia by colonic absorption of ether. In: Gwathmey JT, ed. *Anesthesia.* New York: D Appleton and Co., 1918:433-57.
10. Kabin I. On the medical historical development in Dorpat and Lund and their common doctors (Swedish). *Lund: Sydsvenska med.-hist. Sällskapet*, 1966:103-18.
11. Pirogoff NJ. *Lebensfragen, Tagenbuch eines alten Arztes.* Stuttgart, 1894:374-6.
12. Plum PA. Information about medical circumstances in Russia (Danish). *Hospitalstidende* 1868; *2*:5-7, 9-11, 13-15.
13. Strunsky M. *Die Entwicklung der Anästhesiologie in Kussland und in der UDSSR.* Berlin: *Die Freie Universität*, 1981.
14. Duncum BM. *The development of inhalation anaesthesia.* London: Oxford University Press, 1947.

15. Aldrete JA, Marron GM, Wright AJ. The first administration of anesthesia in military surgery: on occasion of the Mexican-American war. *Anesthesiology* 1984; *61*:585-8.
16. Wanscher O. Anesthésie chirurgicale au moyen de lavement de vapeur d'éther. *Comptes rendus du congrès périodique international des sciences médicales*, 1884. 8me Session. Tome 1. 5. section chirugie, Copenhague 1886:186-9.
17. Cunningham JH, Lahey FH. A method of producing ether narcosis by rectum, with a report of forty-one cases. *Boston Medical and Surgical Journal* 1905; *152*:450-7.
18. Gwathmey JT. *Anesthesia*. New York: D Appleton and Co., 1918.
19. Seedorff M. Rectal Æthernarkose. *Danish Surgical Society* 1921-22:635.
20. Bowes JB, Zorab JSM. Sir Ivan Magill's contribution to anaesthesia. In: Rupreht J, Lee JA, van Lieburg MJ, Erdmann W, eds. *Anaesthesia: essays on its history*. Berlin: Springer-Verlag, 1985.

Further reading

1. Djørup F. Nicolaj Iwanowitsch Pirogoff and his time. (25/XI 1810-5/XII 1881) (Danish). *Bibliotek für Læger* 1972; *164*:3-37.
2. Halperin G. Nicolai Ivanovich Pirogov — surgeon, anatomist, educator. *Bulletin of the History of Medicine* 1956; *30*:347-55.
3. Hirsch A. ed. *Biographisches Lexikon der hervorragenden Aertze*. Leipzig: Urban and Schwarzenberg. 1886.
4. Robinson V. *Victory over pain*. New York: H. Schuman. 1946: 169-71. (This contains a short article by Pirogoff, reprinted in English. The article was published in a journal on 2 April 1847, but there is no reference. It may have been published in a German or Austrian journal. The content of the article is very much like the content of Pirogoff's first message to the Academie des Sciencess).
5. Talbott JH. *A biographical history of medicine*. New York: Grune and Stratton. 1970.

RESEARCHES

PRACTICAL AND PHYSIOLOGICAL

on

ETHERIZATION

INTRODUCTORY DISCUSSION

The experiments I have performed on sick and healthy persons, on myself, and on living animals, enable me to voice an opinion on the practical value and the mode of action of ether on the animal organism.

It might perhaps be safer to defer the expression of my opinion until I had accumulated an even larger experience but, since it is always open to such additions to confirm, change, or even refute conclusions based on previous observations, no matter how numerous, I venture to publish

provisionally the results of fifty surgical operations, as well as forty experiments on healthy individuals and several experiments on animals, in the hope that this research may prove of general benefit. At the same time, I have wanted to publish as soon as possible the information *on a new method of etherization* which I have been using for several weeks with great success. I undertake, moreover, to report any additional tests I may yet perform, even if their results contradict what I am announcing today.

Notwithstanding the spectacular successes described by the newspapers in London and Paris, relating to the sedative effect of ether in surgical operations, I must confess at once that hesitation and even aversion attended my initial decision to administer ether vapor by the respiratory route. Not that I doubted its sleep-inducing action, but my mind-set against the subsequent excitatory effect of ether was still very strong.

Like all physicians, I was well aware that people intoxicated by wine feel traumatic stimuli hardly at all. By intoxicating my patients with alcohol I had often reduced chronic dislocations without the least reaction or sign of pain on their part (*see my published reports*). I had also seen patients afflicted with *delirium tremens* jump out of bed and dance on their shattered limbs without apparent pain. There was even a case in our hospital of a highly inebriated patient who in a fit of *delirium tremens* leaped out of a window and sustained a compound dislocation of the foot (with the tibia projecting from the wound), and then proceeded to trip about on it merrily quite heedless of pain. It was also known that inhalation of the vapors emanating from wine readily produces profound intoxication, as happens in old wine cellars for instance. One recalls that *liquor anodynus* has been from time immemorial a resource in major surgical operations, at first employed for sedation, as indicated by the Greek meaning of the word, and later as a stimulant. Never-

theless, I remained unconvinced that ether vapor's inevitable action on sensibility would be innocuous and that its effects would promptly dissipate after the inhalation was terminated.

One other consideration made me hesitate about using this remedy. To a surgeon steeled by courage, judgment, and experience to disagreeable and unwelcome screams and reactions to pain of his patients, an operation performed on a person robbed of feeling and consciousness is bound to be repugnant. Moreover, it is well known that major operations are prone to unexpected complications in which the patient, a moment earlier happy, jolly, and full of life, suddenly becomes completely insensible or even dies of nervous apoplexy or entry of air into the veins.

Is it possible to foresee such accidents while one is operating on a man deprived of sensibility and the use of his senses, or know when to stop and apply the required remedial measures? Furthermore, doesn't surgical practice present many a case where the patient's consciousness and thought are indispensable to the performance of the operation, as when we call on the patient to modify the posture of the operated limb in tenotomy for lengthening a tendon, or to cooperate by remaining immobile during a critical stage of the operation, or, again, to take a deep breath to stimulate interrupted venous circulation, or even to stop breathing for a few moments? Could a patient deprived of sensibility possibly meet such requirements? And who could accuse us of having hesitated overlong, given that we regarded our patients' cries of pain as inseparable from an operation and as signs of an appropriate reaction? And, finally, haven't midwives and parturients and indeed all others always viewed the agonies of delivery as an indicator of safety and a well-nigh holy accompaniment of childbirth?

But after I had overcome those scruples, doubtless shared by many another surgeon, I became convinced that ether vapor is incontestably a remedy worthy of close attention,

a remedy which, in one respect, can utterly transform the entire practice of surgery. I am referring here in particular to *palliative operations*, a class of operations hitherto restricted to diseases of minor importance.

Surgeons have hitherto resorted to painful operations only with a certain tacit reluctance if their sole aim was to prolong life or temporarily mitigate the patient's agonies and make existence more bearable alike to the sufferer, to his companions, and to other patients (in hospitals). They were extremely discreet in the presence of the patient and even his next of kin — can any patient be resolute and judicious enough to endure a painful operation that promises only temporary relief? Yet such challenges are not infrequent, especially in hospitals, and honest and conscientious operators admit that in cases such as extirpation of a cancer the procedure is purely palliative.

Anyone who has seen pale, haggard patients exhausted by unendurable pain, discouraged and even in despair because of profuse suppuration, and observed them after operation, free of pain, at rest and often with a healthier complexion (unfortunately temporary or enduring at most for one or two years), will unhesitatingly agree that even a purely palliative operation is in such cases a humanitarian and sacred duty.

Every hospital physician has seen cases of spreading ulceration develop profuse, stinking suppuration, unbearable and dangerous not only to the patient but to all his neighbours and which the physician knew to be obviously incurable.

Personally, I admit that at the patient's earnest entreaty I have in such cases resorted to a purely *palliative* operation solely for the purpose of decreasing the danger to other patients.

I recall, for example, a case of tumorous ulceration with osteomyelitis of the femur who developed such a profuse

stinking suppuration that it soaked the mattress in a few hours and disseminated a stench unbearable alike to the patient and to the attendants. The patient herself begged me to amputate, and though I knew the disease to be incurable I finally felt unable to refuse the requested relief : she survived the operation for a few weeks, rid of her unbearable pain and suffering.

In many instances one cannot be certain that an operation, even if undertaken in the most unfavorable circumstances, has no chance whatsoever of success. Every surgeon not in pursuit of fame and a reputation for luck has surely more than once had the pleasure of confirming the truth of the Hippocratic saying: *anceps remediam quam nullum*, and I am firmly convinced that an operation undertaken for purely palliative purposes may occasionally actually save a patient's life. If palliative operations have hitherto been rare, if most surgeons have limited them to a puncture or small incision, it is for humanitarian reasons and out kindness: the physician himself has felt that the patient pays too dearly for the brief pain relief and that the agony of the operation far outweighs the patient's transient subsequent improvement. Obviously, such scruples evaporate the moment one has a remedy that suppresses the pain of operation, and the indications for palliative operations then correspondingly expand.

The first somewhat significant operation in which I made use of ether inhalation was as follows.

A woman aged 35, of weak constitution and nervous temperament, had for several years noted a hard but movable lump in her left breast. After her last pregnancy it had grown in size and become highly inflamed. The tumor had all the hallmarks of a medullary cancer, accompanied by axillary glands that swelled and tended to ulcerate. Soon both tumors, that of the breast and that of the glands, burst, and frank cancer became apparent at both sites. High fever

developed and the patient became exhausted and extremely irritable. Before the onset of ulceration she had steadfastly refused operation, and now it was evidently too late. Purulent infiltration of the axilla with erysipelatous inflammation and bouts of shivering supervened. But after overcoming these complications we were surprised to see the axillary ulcer mend, leaving only an egg-sized adherent swelling. Meanwhile the breast cancer remained *in statu quo* and the patient became visibly exhausted by suppuration, pain, and fever. The patient herself then insisted on an operation. Complete extirpation of the axillary glands was impossible because they were adherent to the indurated cellular tissue surrounding the neighboring vessels and nerves, although not very painful and unlikely to suppurate. Aiming only at palliation, I undertook the operation, encouraged by having at hand a means of decreasing the surgical pain. But first I wanted to determine the effect of ether in her weakened and irritable condition. A test performed on the day prior to operation showed that she was easy to put to sleep. On awakening she felt abashed and on the verge of tears. She had dreamed of saying goodbye to her parents and of leaving the hospital, and her dream may also have had an erotic element, for after coming to she clutched my coat and pulled it over her eyes, saying 'I am ashamed.'

The preliminary induction of sleep before the operation occupied about eight minutes. The operation consisted simply of removing the breast, which took only about two minutes. The patient had lost all sensibilitty. A group of degenerate glands in the upper angle of the incision was seized with Museaux forceps and ligated *en masse* at its base. Neither this nor ligation of the vessels partly bound to muscle and nerve fibers evoked the slightest manifestation of pain. The patient came to in about eight minutes and immediately asked why the operation had not been performed. She seemed to remember my last remarks as in a

dream but remained insensible long enough for me to apply two more ligatures. A little headache and nausea were the only sequelae. These lasted until evening, at which time neither the febrile reaction nor the progress of the incision showed anything unusual.

Again for palliative purposes, I used ether vapor on an utterly exhausted girl who had developed purulent phlebitis after amputation of the thigh (for organic disease of the knee). The stump was hypersensitive, and dressing it provoked such heart-rending cries from the poor victim that I felt it my duty to make her inhale ether on these occasions — the first time from Charrière's apparatus, on the other two occasions by direct nasal inhalation from a bottle. In all three instances sleepiness developed quite promptly and without any sign of pain, although she told us that she had clearly felt each of the dressings.

In order to popularize the use of ether and foster confidence in its surgical efficacy, I believe it is essential to warn physicians and patients who employ it for the first time:

1. That prior to suppression of sensibility the *effect* of the remedy is quite variable.
2. That trouble-free, successful etherization depends critically on the *construction* and mode of use *of the apparatus*.

For, despite the novelty of etherization, there have already been enough observations and experiences to formulate some very useful rules for its use, rules which will serve as a reasonably safe guide for all who seek to utilize it.

As to the varied *effects* of etherization, those I observed in patients and healthy subjects may be classified as follows:

1. Ether *quickly caused somnolence.* After a few breaths the subjects fell imperceptibly into a gentle, dreamless sleep free of hallucinations.. A pleasant feeling of interior warmth invaded the body from the periphery, beginning in the extremities. The hands became limp, the eyes closed, and a certain lassitude similar to bodily fatigue preceded the onset of sleep. The pulse, at first accelerated and frequent, became slower and smaller; respirations, initially a little rapid and labored, became deeper, and the inspirations so-to-say more eager, while the face became a little flushed and the forehead sweated profusely.

Sensibility either ceased completely or left only a feeble memory of previous sensation. I have twice experienced such an effect on myself and have also seen it produced in one of my colleagues and in the debilitated young girl amputee mentioned above. All three of us have a nervous temperament and my colleague is somewhat prone to cephalic congestion. Ether vapor had a prompt and abrupt effect on me, and what seemed most remarkable was the inexpressibly pleasant feeling of warmth which went right into my toes, ordinarily so cold.

In the first experiment I didn't want to become completely narcotized. It was quite an effort for me to lay the tube of the apparatus aside. I was vividly aware that a few more breaths would cut me off from the external world. I collapsed helpless, yet had the impression that it was no ordinary intoxication but a state intermediate between drunken stupor and fainting. My companion developed a marked nystagmus without being aware of it.

Very recently I have observed this self-same effect of ether vapor in a fairly weakened 50 year-old patient suffering from a three-day incarcerated hernia. Etherization lasted about eight minutes and was followed by deep sleep; his

pulse, initially very thin as in all acute abdomens, became a little stronger. He hardly moved during the operation and didn't feel it at all. Afterwards, all he could say about the effect of the ether on himself was: "I breathed, I breathed, and I fell asleep."

In all these cases sleep supervened without any need to close the nostrils, by using an effective and pleasant method for inhaling ether vapor which I now employ in all cases (*see below*).

2. Ether vapor also caused sleep *directly*, but more deeply, with stronger cephalic congestion and with marked pupillary dilatation and *cataleptic symptoms,* accompanied by complete, or almost complete, insensibility, and again devoid of *hallucinations.*

Also belonging in this category was another patient of strong constitution who had a phimosis, in whom I used ether inhalation for the first time while circumcising the prepuce and incising the internal lamella. After five minutes of inhalation his face went blue, his pulse, which had been very rapid, slowed down, his eyes stared fixedly with pupils widely dilated, his hands and fingers became rigidly extended, yet all he remembered of the operation was feeling a slight prick. He seemed to reawaken as from a deep swoon, looked around in amazement, made the sign of the cross, asked for a glass of water, and in every way behaved after the operation as if it hadn't been performed at all.

Another very curious and, in my experience, unique happening occurred in a thin, pallid young student who had a slight spinal irritation and whose soul's passions were consequently easily aroused - he often felt his lower lip tremble at the slightest excitement. He went into a typical cataleptic trance, eyes staring and protruding from the orbit, pupils dilated, face slightly cyanotic, large amounts of

saliva drooling from the mouth, pulse at first strong, then becoming weaker, forehead bathed in cold sweat, fingers extended. One could bend his fingers, wrist, forearm, and arm and have them remain in any position. For the first time in my life I was confronted with the terrifying spectacle of a man staring fixedly like a marble statue, showing only the white of his eyes, arm raised and limbs immobile in any imposed position, like a wax dummy. Sensibility had been completely lost. When the etherization was discontinued the young man's mind recovered quickly but he remembered nothing at all of what had been done to him.

3. The inhalation of ether may lead to drowsiness accompanied by more or less vivid *hallucinations and dreams* with *no*, or with at best *partial, loss of sensibility*. I have already observed this on several occasions. A robust young soldier who, though not a hardened drunkard was no stranger to spirituous liquors, underwent the influence of ether on two occasions for removal of enormous cauliflower condylomata surrounding his glans penis. He inhaled the ether for a quarter of an hour, his face became very red, his pulse accelerated, the pupils dilated. With a highly amused look he forcibly pushed the apparatus away, burst into roars of laughter and exclaimed: "What are those rabbits I see running about?" He had also dreamed of sweeping the snow off a roof. The second time he was more dazed and his hallucinations were apparently cut short by the pain of the operation. He groaned loudly and told us later that the pain had penetrated him to the core, although his account suggested that it was less intense than expected.

A vigorous and healthy student, who tested the effect of ether vapor on his own person in my presence, replied in writing to my questions about his condition. He first felt a pleasant warmth in his limbs, then, after having breathed ether for 40 minutes he wrote in a firm hand that he felt as

if he was flying on clouds and that while asleep he had been the leading actor in a dream, the content of which he was, however, unable to specify. His pulse accelerated, his face became flushed, but sensitivity remained intact. The slightest pressure of a needle against his foot was clearly felt and he seldom erred in identifying its site of application. Slight headache and a catarrh (perhaps the result of a chill) that lasted until the next morning were the only *sequelae* of the experiment.

4. Profound intoxication, various more or less vivid hallucinations, and *complete insensibility* constitute the commonest state produced by the inhalation of ether. Most of the persons I have etherized, whether patients or healthy and young, went into a state closely resembling wine-induced drunkenness. Their intoxication progressed in various ways, sometimes being preceded by axcitement, sometimes setting in slowly and quietly, without the least sign of excitement.

In the first group one sees all the signs of cephalic congestion: shining eyes, lachrymation, injected conjunctiva, merriment, laughter, shouting, swearing, singing, comic or threatening gestures, rhythmic tapping of hands and feet, in brief drunkenness, until somnolence is complete.

Others in this group become excited to an extreme degree. I have seen patients jump about, dance, and hit themselves. One of them attacked the surgeon, whose instrument had touched the diseased part *(glans penis)*, so vehemently that the operator was compelled to flee to another room.

In the second group, after just a few breaths the eyes become fixed and atonic, the pupils dilate, the eyelids gradually droop, respirations become deeper and slower. Some inquisitive subjects deliberately paying careful attention to what was happening to them told me that before becoming completely intoxicated they heard bells ringing in their ears

and other musical sounds and could see objects more distinctly, as if bathed in a strange yellow light. The assistants seemed to grow bigger or smaller, which made the subjects laugh uncontrollably, while the shapes of other objects and their own bodies became less and less clear.

As for the hallucinations, they may be classified as follows:

a. Hallucinations resembling those of the inebriated. Such persons, once the apparatus is removed, behave as if drunk, gesticulating, swearing, laughing, and jabbering incoherently about commonplace matters of no particular interest, or else:

b. Visions of seemingly greater psychic significance. Some individuals, on awakening, behaved drunkenly but spoke coherently in a firm voice and with great emphasis, more nearly like a hallucination than a dream.

The hallucinations concerned surrounding objects, the assistants or the subject's preoccupations, or a higher sphere most often agreeable and amusing. Some students hallucinated their doctorate diploma. One of them, who was interested in music, heard a well-known march being played, while a soldier saw a vision of the Holy Virgin, etc. etc. Among the patients about to be operated on the hallucinations sometimes related vaguely to the pain of operation, in which case they might be either unpleasant or the reverse.

Perhaps most curious of all was the tale told by a 10-year-old child who had been bitten in seven different places by a rabid dog. With the aid of ether and a red-hot iron I cauterized all seven wounds. During the operation the child seemed to feel nothing at all. After I removed the apparatus he rubbed his eyes, gazed with surprise at the assistants,

and said: 'What on earth does this mean? I am asleep, and yet I can see you all. Why are you all so tall and as high as the ceiling, and where are the boys with whom I was playing *babkis* (a national game played with ossicles)?' It took a few minutes for him to feel the seared wounds and see his cauterized arm, whereupon he exclaimed, 'Ah! Now I know, the boys pinched me' and bursting into tears cried, 'I know, I know all, I saw all, you burned me because I am only a poor orphan! . . . I don't want to stay here any more.' And having uttered these words he attempted to leave. Another boy whom I had operated for stone, when asked to describe his dream, replied that he had been walking on a carpet of flowers.

A soldier from whose neck I removed some large degenerate lymphatic glands and who uttered curses throughout the operation dreamed that he was fighting his comrades. Another, whom I circumcised, saw himself being hurled into an abyss (the woman operated on by Professor Wattman's in Vienna, on the contrary, thought she was in paradise). Lastly:

> c. The intoxicated subject on awakening remembers having hallucinations but forgets the details and for a while remains silent and dazed, unable to understand what has happened. A student who submitted several times to being etherized for the purpose of retracing his dreams had completely forgotten them by the time he awoke. Of three amputees, not one was able to recollect anything of the etherization or operation, all three were unable to say whether they had had any dream or not.

5. Yet another curious condition which develops after ether inhalation is sleep with complete loss of sensibility, accompanied by *violent spontaneous body movements.*

At the beginning of narcotization I have often noticed that subjects become anxious, seize the tube of the apparatus and make repeated attempts to evade it. One student, whom four friends were unable to prevent from rejecting the apparatus, was totally unaware that there had been a struggle and reproached them for having removed the equipment. Another submitted to excision of a cyst from behind the ear while under ether but struggled so violently that five assistants were unable to hold him in the required posture; yet on awakening he remembered neither the incident nor the operation. Similar involuntary movements and groans occurred in a patient who felt not the slightest pain while I operated on him for phimosis. If the patient unwittingly tries to seize the apparatus I often interpret that as a reliable indication of the onset of narcosis.

6. Etherized subjects may *retain consciousness* to a greater or lesser degree but partly or completely *lose sensibilty*. One patient I operated on for recto-vesical fistula continued talking throughout the operation. He heard and saw everything, stiffened his thighs, and felt the procedure was taking place but did not experience any pain. Another patient, a highly timorous lachrymose person on whom I incised a deep fistula secondary to empyema, remained silent and motionless during the operation, but claimed to have watched me throughout. After the operation, he screamed when I put my finger into the wound.

It seems likely that some patients who report experiencing pain in reality felt hardly any at all, since they remained quiet during the operation, or at least quieter than usual. I noted this recently in a lady on whom I undertook partial excision of the peroneal fascia. Although very nervous, she kept quiet during the operation except for an occasional groan, yet later she reported she had felt everything.

I do believe, however, that (despite their being exposed

to ether for as long as other patients) most of these cases are in a state of incomplete narcosis, and would have attained complete sleep if the ether inhalation had been continued.

7. Finally, some subjects, despite a lengthy inhalation of ether, *do not become* intoxicated, *or only very little*. I include in this group all those are intent on watching things very closely, as well as all fearful, worried, or suspicious ones, and especially those habituated to strong liquor.

A physician and a student, both of them of very strong constitution, had proposed to observe and fully describe every detail of their sensations. After inhaling ether from the Charrière apparatus for three quarters of an hour — three times longer than usual — they noted a delightful feeling of warmth, a lassitude, a certain giddiness and pleasant feeling of relaxation, but never lost either sensibility or consciousness. I have also noted this in two other physicians: they seemed to become inebriated and staggered a little on standing up, but their voice was unaffected and their sensibility and consciousness were quite unimpaired.

Here I must point out that successful obtundation demands considerable self-control and composure. That is why etherization sometimes fails in timorous, suspicious and ignorant patients who become frightened by the preliminaries or the presence of a large group of assistants. Fear is well known to be an antidote of inebriation.

To become narcotized smoothly and completely one has to breathe in very slowly and very deeply. An apprehensive, distrusting patient, however, takes only short breaths and worries incessantly about his condition, so that as soon as he feels anything unusual he frantically tries to break away from the apparatus.

———

I can confirm these principles with a number of examples:

A certain Finnish patient was suffering from a deep, chronic anal fistula with thinning of much of the rectum. He was terrified of the operation and submitted to it only with great reluctance. After a few short breaths he began to feel the effects of the ether and refused absolutely to continue the inhalation. First he tried to pull away the apparatus, then he jerked his head away, or time and again stopped inhaling and begged me to proceed with the operation. What he found particularly unpleasant was having to inhale through the nose. He trembled and became all excited and despite our best efforts for half an hour it proved impossible to narcotize him completely.

A soldier from whose neck I excised some degenerate lymph glands behaved in exactly the same way. The first time I etherized him he became highly excited, violently eluded the apparatus, and weepingly beseeched me to simply go ahead and operate. I calmed him with a dash of cold water and postponed the procedure to another time. A few days later he found the inhalation much less alarming and underwent etherization fairly quietly; it took a little longer than usual but he did become completely narcotized and felt nothing at all of the operation. He declared afterwards that he hadn't the remotest idea what had been done to him.

An employee from whom I removed a small facial cyst also was unable to attain sleep. After inhaling the ether vapor for a while with every sign of fear and aversion he declared that he preferred the operation to proceed without inhalation.

Quite recently, again, a 70-year-old lady submitted to a difficult examination of the bladder, performed under the influence of ether in order to make things easier for her. She was utterly terrified and hardly allowed the hand to touch

her genitalia. She groaned anxiously throughout the ether inhalation and though it certainly mitigated the pain of the examination she never became fully narcotized. She continually interfered with the examination by convulsively clutching my hand.

Henceforth I hope to improve the reliability of ether inhalation and make it less dependent on the patient's cooperation, with the aid of an apparatus of my own design *(see below)*. However, the will power and mindset of the subject will, in my opinion, always affect the success of the procedure, especially in persons of strong constitution unweakened by their illness. That is precisely why etherization via the rectum is so advantageous. Its action by this route is virtually inevitable and quite beyond the control of the patient's will. Nowadays I use it invariably and will describe it later on.

At present, however, I want to stress certain points about the effect of ether on the human organism, effects which I consider to be of great importance to surgical practice.

1. One of the most consistent signs of narcotization induced by inhaling ether vapor is dilatation of the pupils. If the patient's face is not directly in the light one has difficulty in noticing the initial narrowing of the pupil, which quickly disappears and gives way to dilatation. I have seen a persistent narrowing only in one case, that of the Finnish farmer in whom narcotization was only partially successful. I have on the contrary several times observed extreme mydriasis, such that one could hardly discern the edge of the iris. The change in pupil size is nearly always accompanied by a peculiar glint in the eye, merry or mocking and eliciting a smile, or atonic and immobile.

The condition of the eye is occasionally very propitious for the performance of surgical operations on the organ: the eyeball remains stationary and the palpebral fissure open. If narcotization is complete the eyeball continues stationary, or may protrude and its anterior part become tense and turned upwards. However, in other cases the eye squints and moves from right to left so spastically that performance of the operation becomes if not impossible at least very hazardous. The palpebral muscle invariably relaxes, so that spastic entropion, a very awkward complication of eye operations, is avoided by the etherization, but at the price of a conjunctival congestion which may seriously compromise the outcome of a major operation on the eye.

2. One must not expect that feeling will always be abolished to the point that operation can proceed without some protest by the patient — screams, groans, gestures, or interfering movements.

Many difficulties can be avoided by proper design and proper use of the apparatus, but I have become convinced that, notwithstanding seemingly complete sleep and the patients' denial that they felt any pain during the operation, some of them do experience pain or fairly unpleasant sensations which they quickly forget. Nightmarish groans or actual screams accompanied by tentative movements of escape tell me that in such cases feeling has not completely ceased. That's exactly what I concluded in one case on whom I was performing a herniotomy. Although the patient was completely asleep and bereft of feeling he persistently tried to protect the diseased parts every time I touched them. But such sensations can be forgotten just as readily as dreams and hallucinations. Also, some patients who neither screamed nor groaned have asserted that they saw the entire operation but were unable to cry out. Some healthy volunteers whom I etherized said that they did feel the needle

pricks but that a peculiar inertia or indifference prevented them from expressing pain.

As to the signs of adequate etherization, in most cases one can probably infer absence of feeling and consciousness quite accurately from the appearance of the eyes and the slumped, relaxed state of the body, the slow respiration and pulse, and the insensitivity to pinprick. However, I have also seen quite a few narcotized persons fail to respond to a deep pinprick yet scream during the incision. Conversely, I have seen cases where a needle-prick elicited convulsive movements in the total absence of feeling.

3. Another peculiar effect of ether vapor is the unusual state of the muscular system. As already mentioned, if consciousness has been completely abolished the muscles may relax or behave in an unusual manner.

Usually the voluntary muscles and sphincters are relaxed (but remain contractile) whereas the involuntary muscles contract as strongly as ever. Sphincteric relaxation with incontinence is rare, in fact I have so far never observed it. During lithotomy one very young patient did indeed forcibly expel some excreta, but, as is well known, this can also happen to the unetherized.

Muscular relaxation with loss of sensibility is of course highly advantageous during the reduction of chronic dislocations, dislocated fractures, and incarcerated hernias. I obtained profound muscular relaxation in a dislocation of the foream of three months' standing by bathing the part in warm water for two hours during prolonged etherization. I applied the pulley for five minutes intermittently, then forcibly bent the forearm, audibly tearing the adhesions, and flexed the joint without the patient feeling the least pain (although the olecranon process would not seat in the posterior fossa on the humerus).

Reflex movements, on the contrary, generally do not

cease with the administration of ether, even in completely narcotized patients. There was a 10-year-old boy with stone. After he became completely narcotized I gently touched his anus with my finger, and every time I did so his lower limbs twitched convulsively. In etherized animals, too, fingering the anus evokes an immediate strong contraction of the *sphincter ani. (See below).*

But the voluntary muscles are not always relaxed by etherization. As previously noted, the operator must be prepared for convulsive muscular contractions and automatic movements to occur. I am not referring here to the generalized muscular agitation, a kind of frenzy which ether produces in some individuals and which may be overcome by prologing the ether inhalation. Convulsions, automatic movements and catalepsy are, on the contrary, liable to develop unforeseen in the fully narcotized, and greatly increase the difficulties of the operation when they do. In the four cases in which I have seen this happen the operation became much more difficult and its duration was greatly prolonged. In one patient with anal fistula the limbs became so rigid that two strong assistants were unable to separate the legs.

In another case the difficulties of operating for trichiasis were aggravated by incessant movements, although the patient's head and body were firmly grasped by several assistants.

Inevitably, such conditions may render delicate operations like ligation of an artery or excision of a deep tumor virtually impossible. If the operation can be delayed it becomes very important to perform a preliminary trial etherization to test the individual's reaction. Even the most cantankerous and stubborn patient may, provided he is conscious during the operation, be persuaded to keep still by fear of dangerous blood loss, etc., etc., but when etherized, is naturally deaf to all entreaties, and the strength of the

assistants is not always equal to maintaining the necessary exposure in regions such as the neck.

Besides, I've noticed that most etherized persons exhibit involuntary movement up to a point, and I take it as a sure sign of the onset of narcotization if the patient involuntarily tries to seize the tube of the apparatus. That is precisely the moment when one must watch the patient most closely, because it decides whether the muscular system will become completely relaxed or will develop a peculiar and extraordinary excitability.

4. Finally, as regards the sequelae of etherization, they too are not always uniform. Insensibility to pain usually persists for some time after the operation and the patient has recovered consciousness. Most patients remember only impressions from the moments immediately before awakening, such as spoken words or the last steps of the operation, and think they've been unconscious a very long time. In three amputations which I performed I included nerve fibers in arterial ligatures and cut atrophied muscle fibers and residual synovia of the joint capsule without the least sign of pain from the patients. Also, etherized subjects tolerate the presence of water in the wound with equanimity, although this would otherwise be highly stimulating. The absence of sensibility was even more striking in a patient on whom I performed a Chopart disarticulation: placement of an ether-impregnated sponge in the wound was entirely painless; of course, ether applied to exposed nerves certainly depresses feeling, as we shall see later, but unetherized patients are extremely sensitive to such a procedure.

Pupillary dilatation, facial pallor, lassitude, lightheadedness, and headache, such are the more or less persistent sequelae of narcotization. In my own case, for example, one day, after I had etherized several subjects and taken several breaths of ether myself, my pupils remained

dilated and I felt sleepy for the rest of the day, with a headache and a colicky transverse colon abdominal ache such as I have also encountered in two other individuals. I have seen some patients become melancholic and quasi-hysterical and weep after etherization.

It is true that on occasion etherization is followed by a totally opposite mood, as in the patient who, after I reduced a chronic dislocation, became excited and boisterous and persistently went on talking and singing. An officer from whom I excised a cyst of the forehead became almost maniacal. In other cases, recovery of consciousness may leave a residual pallor and a stuporous apathy which ends with the patient unaccountably bursting into tears.

Sometimes they also become nauseated or vomit. One patient began to sob while inhaling the ether and then threw up several times. Massive vomiting such as follows excessive consumption of wine developed in two persons who took ether vapor soon after dinner.

In none of my cases did the febrile reaction exceed that of an ordinary operation, and postoperative wound pain was generally diminished rather than increased by etherization.

Also, I encountered no complication involving the respiratory organs even though the history of several of the etherized patients suggested a predisposition to pulmonary tuberculosis. Neither the case with chronic empyema nor the one with tuberculous neck glands, who must surely also have had diseased bronchial nodes, developed any bronchial or pulmonary irritation. The same applies to two other patients — one with frank tuberculous necrosis of the lower jaw and suspicious sounds in the upper lobe of the left lung, the other with an externally communicating tuberculous deposit under the periosteum of the great trochanter.

Accordingly, I view the sore throat attributed to ether by some French and German observers as avoidable and due to the error of commencing with excessively deep ether

inspirations. Obviously, all these disadvantages will be avoided by etherization *per rectum*, as I shall describe.

After etherization, the sweat and urine usually continue to smell of ether for 48 hours. Whenever excitement or depression persist too long after etherization, I cut them short by pouring cold water over the head or splashing it in the face, or by offering a drink of cold water. This stratagem has worked equally successfully in animals when I wanted to awaken them immediately from stupor.

As regards the mode of action of inhaled ether on the central and peripheral nervous systems, the muscular system, and the blood, I refer my readers to the animal experiments described later. Here I first discuss *indications and contrindications,* as far as they are presently known.

From what I have said, one may in my opinion draw the following conclusions:

1. Although ether by inhalation is indicated in all major and painful operations, the diversity and unforeseeability of its effects on the muscular system mandate a preliminary test, both for the purpose of defining the effects in any particular patient and increasing the confidence of suspicious, ignorant, or unreasonable ones.

2. If the required operation will be a delicate one and not very painful and if the preliminary trial produced excitement *(convulsions, catalepsy, automatic movements)* it is best not to use the inspiratory method of etherization.

3. In some eye operations the procedure may be faciltated by the fixedly-open staring eye and dilated pupil; in others, it becomes more difficult because of an upwardly turned eyeball, injected conjunctiva and automatic head movements.

4. In operations on the mouth and throat the procedure may be hindered by spasm of the jaw, a poorly fitting apparatus, or the difficulty of clearing the mouth of blood and salivary secretions stimulated by ether. Attacks of coughing caused by the easy entry of such liquids in the rima glottidis are also to be feared.

5. For lithotrity I believe that etherization is just as convenient as for other surgical operations, although it has been objected that prediction of the duration of this operation necessitates prior knowledge of the degree of irritability of the bladder. It is, of course, perfectly obvious that the presence of such irritibality can be ascertained by probing the bladder with the lithotrity instruments and by injecting cold water before starting the etherization.

6. In cutting for stone, etherization facilitates the most difficult step, that of extracting the calculus, by relaxing the abdominal and perineal muscles. I have found this to be so in two boys and one farmer. No woman in labor has suffered rupture of the perineum when etherized. But I was forced to admit in another case of stone that ether vapor is sometimes unable to overcome vesical spasm.

7. Etherization has much to offer in the treatment of incarcerated hernia and recurrent dislocation, especially when applied by the method I propose *(see below)*. Hernial reduction is facilitated by the muscular relaxation, quite apart from the abolition of sensibility. In the case of chronic dislocation already mentioned, reduction was effected after a very brief period of traction (5 minutes) notwithstanding the subject's remarkable muscularity. This also applies to oblique fractures of the femur which, in strong individuals, sometimes provoke powerful muscular spasms. *Forcible extension* preceded by tenotomy can be performed with

etherization, which abolishes sensibility and produces a very beneficial relaxation of the muscles.

8. In every case a preliminary test will aid in deciding whether or not the individuality of the patient is propitious to etherization. But it is most important *not to use inhalation of ether* in patients strongly predisposed to cephalic congestion or hemoptysis.

9. Lastly, for therapeutic purposes, it is possible to use inhalation of ether conjointly with other substances soluble in ether. Inhalation of camphor together with ether vapor shows great promise. In a typhoid patient already beyond hope (he had an enormous collection of pus in the anterior abdomen) I used this to surprisingly good effect. The tongue became moist and the pulse strongter, although of course only for a short time.

I have also attempted to introduce quinine into the body by this stratagem on two occasions. In a preliminary test I noted that ether vapor containing quinine sulfate had an excessively bitter taste but I decided to go ahead anyway — with indifferent success — because the illness did not present as a simple intermittent fever. A few days after the treatment it became apparent that the patient's lungs were affected and they now present advanced phthisis. I believe that in this case the feverish attacks merely signaled latent tuberculous disease of the lungs and probably also of the spleen, which the prevailing weather (in March) rapidly aggravated. Still, it remains true that the respiratory route enables one to act on the respiratory organs much more efficaciously and to introduce a great many substances into the organism. To use ether by inhalation successfully, that is, to achieve insensibility and muscular relaxation without causing discomfort to the patient, *two* points are essential: the apparatus must be properly constructed and it must be

applied with precision, deceptively simple as this may seem.

As to testing the first requisite, it is easy enough to narcotize oneself by holding a bottle of ether to one's nostril and inhaling strongly. Two physicians tried the experiment on themselves. They breathed ether and air alternately in equal amounts by holding the bottle near one nostril, thereby avoiding cough and tracheal irritation. After becoming accustomed to this they occluded one nostril and held the bottle right up against the nose, exhaling through the mouth or the other nostril while occasionally shaking the bottle to encourage evaporation. They continued in this manner for an entire hour. One of them achieved complete narcotization and unwittingly developed a marked nystagmus. The other, who rarely shows he's drunk before losing consciousness, did not become narcotized. Both, however, continued to feel intoxicated for more than an hour, although able to speak coherently and walk a straight line. Next day both of them still had enough residual lightheadedness to dissuade them from having another try, and one of them continued to suffer from disturbed digestion for eight days.

Of course, the above-described simple method of breathing ether isn't always adequate, because:

1. Not everybody is readily susceptible to the effect of ether vapor. Also,

2. Not all patients cooperate well enough to inhale ether vapor from a simple bottle and then exhale. With yet other patients, who wish to cooperate but are very timorous, it is necessary to use a degree of restraint to expose them to the ether vapor.

3. Finally, once unsteadiness has supervened it is necessary to make inspiration and expiration as easy as possible for the patient. That is why Charriére's apparatus and valved instruments in general are to be preferred, although they are still far from satisfying all the practical desiderata.

The principal defects of these instruments are as follows:

1. The process of fitting the apparatus to the mouth and closing the nostrils is very uncomfortable to the patient and requires several hands. Sometimes as many as three or four assisants have to crowd around the patient to attend to the apparatus. One of them has to use both hands to hold the mouthpiece to the patient's mouth; another has to make sure the patient isn't able to reject the apparatus, a third one has to hold the ether bottle, etc, etc. Yet all this is not enough if involuntary movements complicate the induction. As with restless and uncooperative patients in general, it then becomes almost impossible to control the mouthpiece accurately enough to ensure that the patient will breathe through it exclusively. Anyone who has tried the apparatus on himself has probably found breathing with closed nostrils decidedly awkward and unpleasant. In some people nostril closure is superfluous; others, on the contrary, are so difficult to etherize that leaving the nostrils open invites failure.

2. The apparatus has another equally serious disadvantage. In my experience, the rubber tube joining the apparatus to the mouthpiece is excessively long and narrow, hindering respiration and delaying the ether from taking effect. Also, the action of the ether becomes difficult to regulate. I think it is quite wrong to make the patient breathe ether

through the tubes of the Charrière apparatus fully open from the outset. Many people are totally unable to get used to it at the beginning, others start to cough, sneeze, or suffocate, so much so that it may be impossible to persuade them to give it a second try.

Nowadays I usually administer the vapor gently and gradually, leaving the nostrils and the expiratory valve of the Charrière open, and I open the tap only one-quarter or one-third of the way. If the individual is very excitable and suspicious, I first have the patient inhale pure air through the expiratory valve, next I slowly open the tap, then I close off the valve, and it is only after observing signs of incipient narcosis that I begin to close the nostrils, again gradually. Ether vapor inhaled in this manner usually causes no discomfort at all. When initially mixed with a large amount of air it has a very smooth action on the smallest bronchi, the patient becomes accustomed to progressively stronger doses, and gradually falls asleep. To make this even easier to achieve, Mr. Rooch, instrument maker in this city, has added an adjustable tap that can deliver pure air or air mixed with various quantities of ether vapor, thus making it unnecessary to touch the expiratory valve of the apparatus.

I think this modification has definitely improved the usefulness of the apparatus (see drawing) by including:

1. A partial rubber mask *a* covering the nose, mouth and chin, and ending in a tin funnel *b* bearing straps *c,c* which attach it to the head in two different directions; a double steel spring ensures a close fit to the bridge of the nose *d*.

2. A metal tube two inches long, attached to the funnel by screw *e*. As in Charrière's apparatus, the tube includes two valves, expiratory valve *f* and inspiratory valve *g*, no-

table for being convex and close together and consisting of metal rings mounted on leather.

3. Tap *i* allows only pure air to enter by the side-opening *h* or, when turned to different degrees, allows air mixed with different quantities of ether vapor to enter through the lower opening *k,l*, as indicated in the figure.

4. A bottle *m* has a neck *n* which attaches to the tap, and two lateral spouts, the upper one *o* for attachment of the breathing tube and a lower funnel-shaped one *p* for addition of ether.

This apparatus has the advantage that it doesn't need assistants to press it to the patient's mouth. Struggles won't dislodge it. The number of assistants will no longer be a hindrance to the operator (especially in operations on the neck). In private practice there will be no need to augment their number, since the apparatus will be attached to the patient.

The short tube and open nostrils make breathing less labored and greatly improve the effectiveness of the ether vapor, since the short tube enables the patient to inhale the vapor both through the mouth and nose. The tap enables the patient to breathe pure air or a variable quantity of ether at will.

Lastly, the funnel-shaped orifice enables one to continually add small quantities of fresh ether to the bottle. I have learned by experience that it is absolutely essential to add fresh ether to the apparatus while the sponges are still wet. The etherized patient responds at once to the addition of fresh ether to the bottle and narcosis develops much more quickly.

With the standard Charrière apparatus addition of ether was more difficult: the air-current and vapor in the bottle made added liquid sputter out like a fountain.

In summary, after attaching my apparatus over the patient's mouth and nose one first opens the entry port for atmospheric air so that the patient breathes only pure fresh air, then one lets in a little ether vapor through the tap, slowly increasing the dose while at the same time adding small quantities of fresh ether to the apparatus through the funnel.

It remains for me to demonstrate the mechanism of the action of ether on the body's economy. I will begin with a brief account of experiments I have performed for this purpose on living animals. Some readers may feel these notes are too detailed, but animal experiments do not always have clear-cut, readily explained results. Each is apt to present new phenomena which, if neglected by paying attention only to results, may generate false impressions and induce the observer into error, especially if his intention is to verify a preconceived idea.

I will therefore first describe all the experiments in sequence, and then discuss the conclusions which I draw from them. Whether the reader agrees with these or not, he will, if he takes the trouble to repeat the experiments, always observe the same facts as I did.

I. EXPERIMENTS

ON THE LOCAL EFFECT OF ETHER APPLIED DIRECTLY TO NERVOUS TISSUE.

EXPERIMENT I

Dog, average size. — Axillary nerve bared. Galvanic current and mechanical irritation elicit violent struggles and pain.

Ether applied with a sponge: decreased response to galvanic stimulation, absence of reaction to mechanical stimulation.

Exposure of thoracic spinal cord. Light mechanical stimulation of the posterior fascicles produces struggles. Galvanism provokes strong convulsions merely on touching the dura mater.

Transection of spinal cord:

Peripheral (lower) end. Posterior fascicles: galvanism is followed by convulsions without signs of pain.

Anterior fascicles: galvanism is followed by stronger struggles.

Central (upper) end. Posterior fascicles: galvanism and mechanical stimulation are followed by struggling and signs of pain.

Anterior fascicles: struggling following both types of stimulation.

Repetition produces the same results.

Application of ether to the spinal cord for a few minutes:

Peripheral (lower) end. Posterior fascicles: mechanical stimulation is followed by barely perceptible struggles.

Anterior fascicles: Mechanical stimulation produces somewhat stronger struggles.

Posterior and anterior fascicles: application of galvanism, same struggles as before etherization.

Central (upper) end. Mechanical stimulation: termination of struggles and pain; no response to either posterior or anterior fascicles. Galvanic stimulation: same result in posterior and anterior fascicles as before etherization.

Tracheostomy. Inspiration of ether vapor through open trachea: signs of narcotization, pupillary dilatation; automatic movements, strong convulsions following galvanism, weaker after mechanical stimulation of spinal cord.

Experiment repeated. Same result.

EXPERIMENT II.

Another dog, medium size. Spinal cord exposed. Injection of ether through a small opening in the dura mater (3/4 of a syringe*): vapor forms and extrudes liquid.

Injection repeated (1/2 syringe): sudden death. The animal dies as if struck by lightning, without cramps. Heart continues to beat for some time, even after thorax is opened.

Galvanic stimulation of spinal cord: no convulsions, although the muscles remain highly excitable; the heart ceases to be excitable, but limb muscle excitability continues. Posterior parts of lungs are dark; emphysematous areas beneath visceral pleura.

EXPERIMENT III.

Small dog. Spinal cord exposed. Injection of water (3/4 of small syringe) under the dura mater: coma, dilated pupils, front legs stiff. The animal recovers. Two more injections of ether (slightly less than 1/2 syringe):

---

* The syringe that I used in all of the experiments could hold almost three and one-half *gros* of ether.

Initially no change, later deep coma. Throughout the experiment (and also after death) the spinal cord continues to respond to galvanic stimulation. Axillary nerve exposed. Local application of ether: mechanical stimuli over the nerve are without effect, but the nerve remains sensitive to galvanism and, deep to the etherized sites, to mechanical stimulation.

Autopsy: greenish blotches on the lungs, ether vapor in blood in the right heart; the blood is uncoagulated. Repeat experiment: same result.

EXPERIMENT IV.

Small dog. Exposure of olfactory bulb by incision of a dural sinus: extreme sensitivity even to the lightest touch: struggles and howls. Local etherization of the olfactory bulb intermittently for 15-16 minutes: no drowsiness, the dog shakes itself violently numerous times and runs about while rubbing its nose against the floor: the front legs slip repeatedly, voicing ceases, no cries on pinching the toes but evidence of pain is present; olfaction is lost, tobacco smoke and sulfur fumes fail to irritate the nostrils.

Etherization via the opened trachea. Narcotization complete; dilated pupils.

Spinal cord exposed. Mechanical stimulation is almost without effect, only slight convulsive movements, but galvanism produces strong spasms. The animal recovers after administration of ether is discontinued.

Autopsy: Lungs as in experiment III.

EXPERIMENT V.

Dog, large size. Ether inhaled for two minutes through a tracheal incision: pupillary dilation, automatic convulsive movements. Four minutes later, sciatic nerve exposed: complete insensibility, but convulsions follow mechanical irritation.

Ether applied locally to the nerve; rapid cessation of convulsions.

Mechanical stimulation of axillary nerve after exposure: no feeling. but persistence of convulsions throughout the period of etherization. Removal of anesthetic apparatus: very rapid respira-

tions, faster than the heart beat and pulse; one pupil constricted, the other dilated. Shivering; very thirsty. Paresis of the hind leg after exposure of nerve, the dog is still able to stand up but drags the leg on walking.

EXPERIMENT VI.

Rabbit, left hemisphere exposed.

Ether applied with a sponge intermittently for 10-12 minutes. No signs of narcosis, but excitement after each wetting of the sponge: the animal struggles and tries to escape. One half-hour after the animal recovered the brain was somewhat swollen and bulged through the wound; application of ether-soaked sponges for a similar period produced complete narcotization during which the breath smelled strongly of ether. After a while the animal recovered but was extremely restless. Survived for 48 hours.

EXPERIMENT VII.

Small dog. Tracheostomy. Narcotization: complete loss of consciousness. Nerves and spinal cord exposed: no signs of pain. Light mechanical irritation of the dura mater and posterior fascicles of the spinal cord; seizures. Local etherization of the spinal cord for 3-4 minutes; very strong mechanical stimulation, transection of the cord: no convulsions. Light galvanic stimulation: strong convulsions. *Microscopic examination:* blood corpuscles unchanged, spinal cord fibers unchanged. Ether vapor injected subdurally: instant death.

EXPERIMENT VIII.

Small dog. Spinal cord exposed; posterior column touched, pain but no struggles. Dura mater incised, ether injected subdurally with a small cannula: rapid narcotization and loss of sensitivity; the expired air does not smell of ether. After the animal had gradually recovered, convulsions, restlessness, ceaseless body movements, continual groaning. Widespread tremor; sensibility gradually returned. (*Compare experiments IX and XXX).*

II. EXPERIMENTS

ON THE ACTION OF ETHER INTRODUCED INTO THE BLOOD.

EXPERIMENT IX.

Dog, very sensitive. Ether injected into peripheral end of crural artery (1/2 syringe); brief howls. Crural and sciatic nerves exposed: great sensitivity to mechanical stimulation. Ether applied to the nerves: disappearance of sensitivity to mechanical stimulation after a few minutes. Nerve pinched with forceps; no sensitivity at the etherized sites; similarly, none in toes. Galvanism (conducted through nerve): struggles. Severe pain on galvanic stimulation of the sites pinched by forceps; sensitivity also present at etherized sites. Experiment repeated on contralateral sciatic nerve, with same result: disappearance of sensitivity, struggles after galvanic stimulation. Under the etherized sites the nerve remains sensitive.

Ether (about one *gros*) injected in the peripheral (upper) end of the left carotid: great howls, opisthotonus, convulsions and twisting of head to opposite side. Strabismus. Eyes immobile, staring downward. Every least touch provokes convulsions. Heart rate accelerated. The legs of the left side are stiffer and less sensitive to mechanical stimulation, but still very sensitive to galvanic stimulation. Death.

EXPERIMENT X.

Dog , medium size. Thoracic spinal cord exposed. The slightest touch to dura mater and posterior part of spinal cord provokes silent struggles. Strong galvanic stimulation of the same parts — positive pole at the top —: struggles and howls. Injection of ether (1/2 syringe) into jugular vein: dilated pupils. Simultaneous galvanic stimulation of anterior columns of spinal cord: strong convulsions without signs of pain. Sudden death.

Autopsy: Marked dilatation of the right heart by ether vapor, partly clotted blood, dark blotches at lung surface, subpleural bullous emphysema. Convulsions upon touching posterior and anterior columns of both ends of transected spinal cord.

EXPERIMENT XI.

Dog, medium size . Inspiration of ether (from apparatus) through mouth and nose for a long time without effect. Tracheostomy and inspiration, also from the apparatus, through the open trachea: narcotisation, insensitivity to mechanical stimulation. Strong stimulation of exposed spinal cord (the cord was entered deeply by the knife) without the lightest convulsion. Galvanism applied to anterior and posterior columns, convulsions. The animal recovers. Galvanism applied to posterior columns: convulsions and cries. Ether injected into the peripheral (upper) end of the left carotid: sudden death as if struck by lightning, without convulsions. Several minutes later the heart still beats strongly.

Autopsy: Gas bubbles present in cerebral vessels, no cerebral hyperemia.

EXPERIMENT XII.

Small dog. Ether injected into crural vein (20-40 drops) from a syringe rinsed with warm water: frightened howls; sudden death with widely dilated pupils.

Autopsy: Ether vapor in right heart. The right heart also contains dark blood, the left heart, bright red blood. Purple patches in lungs.

EXPERIMENT XIII.

Calf anesthetized in same manner (almost an entire syringeful of ether). The vapor enters the blood stream noisily, without pressure on the plunger; breath soon smells of ether; drowsiness, cries of fear. Dilatation of pupils, convulsions. Death.

Autopsy: Ecchymoses in lungs; the posterior surface is dusky. No vapor in right heart, only liquid blood.

EXPERIMENT XIV.

Large dog. Introduction of the cannula into central end of crural vein; ether vapor, mixed with air; vapor formation encouraged with warm water: death in less than ten minutes.

Autopsy: Ether vapor escapes from the right heart opened under water; the blood is not clotted and remains liquid a long time. The lungs present apoplectic ecchymoses and blotches; ether vapor in the hepatic vein and superficial veins of the skin. Repeat experiment while closing the orifice of the syringe with a piece of membrane taken from the dog's mesentery: same result but the dog dies less quickly.

EXPERIMENT XV.

Large dog. A fine cannula was introduced into the peripheral end of the crural artery. Partly liquid, partly vaporized ether injected (three syringes, while wetting the syringe with hot water). Signs of violent pain, struggles; rigidity and insensitivity of homolateral leg and partial contraction and transverse furrowing of the muscles. Breath smells of ether; after the third injection, complete loss of sensitivity, in other parts as well. Pupillary dilatation, although without complete sleep. The animal is sacrificed.

Autopsy: lungs edematous, with dark blotches. Both sides of the heart are full of coagulated, vapor-free blood. Muscles of the affected leg dark and swollen, with ecchymoses here and there in the cellular tissue.

EXPERIMENT XVI.

Large dog. Injections of ether vapor into the peripheral end of the right carotid: (1/2 syringe of ether and 1/2 syringe of air). A lot of blood escaped, interfering with entry of the ether; one minute later, cries of distress, pupillary dilatation, stiffening of the limbs, cessation of respiration. Death was avoided by removing the cannula; profuse arterial hemorrhage, animal splashed freely with cold water, slow recovery. Automatic swimming movements; howls and whines for nearly one hour. The animal is lying on its left side; next day, lassitude and continuous sleep.

EXPERIMENT XVII.

Large dog. Ether vapor into portal vein: very rapid death, with same signs as with ether vapor introduced into the crural vein.

Autopsy: Large amount of vapor in inferior vena caval blood and right branch of portal vein. Right heart distended with blood and ether vapor, greenish blotches in lungs.

EXPERIMENT XVIII.

Large dog. Very careful injection of ether vapor into crural vein. Audible entry of vapor into the central end, drowsiness, unconsciousness; the animal recovers: cries of distress, body movements resembling obstructed breathing, followed by extreme weakness.

EXPERIMENT XIX.

Dog, medium size. Injection of ether vapor into the stomach; no unconsciousness, but the dog totters as if drunk. Ether vapor injected into the crural vein, great care being taken to avoid entry of liquid ether into the blood. Audible entry of vapor into the central end of the vein; pupillary dilatation. Injection continued: no loss of capacity for feeling. Injection discontinued: howls of alarm, drunkenness, followed by complete recovery of the animal.

EXPERIMENT XX.

Small dog. Cannula introduced into portal vein. Animal becomes apathetic. Ether vapor introduced *via* the cannula. No signs or cries of fear, as in experiment XII. The exhaled breath smells strongly of ether. Complete unconsciousness. Consciousness recovers in one-half hour. Animal sacrificed.

Autopsy: Usual changes in lungs (see the other experiments); dark patches in liver.

III. EXPERIMENTS

ON THE EFFECT OF ETHER INTRODUCED VIA THE TRACHEA WITH AND WITHOUT SECTION OF THE PNEUMOGASTRIC NERVE.

EXPERIMENT XXII.

Large dog (the same one as in experiment V). The animal is exhausted. Both pneumogastric nerves exposed in the anterior lower third of the neck. Galvanic stimulation of pneumogastric nerves. Contractions in the throat, thorax and upper part of the body in general. Transection of the two pneumogastrics; ether inspired through open tracheostomy for 3/4 hour (ether was added three times), sensibility retained in the exposed sciatic and axillary nerves; very violent, almost asphyxial signs with eventual loss of sensibility, which remains very weak after ether administration is interrupted.

EXPERIMENT XXIII.

Large dog. Pneumogastric nerves exposed. Galvanic stimulation. Throat contractions as in preceding experiment. Tracheostomy, transection of pneumogastrics; inspiration of ether from Charrière apparatus: sudden death.

Autopsy: Large dark blotches on inferior lobe of left lung. Galvanic stimulation of left pneumogastric. Right auricle contractions (in two places, in the appendix and at the base). Galvanic stimulation of right pneumogastric; no contractions. Galvanic stimulation of auricle; contraction.

EXPERIMENT XXIV.

Small dog. Tracheostomy. Intermittent inspiration of ether through open trachea: excitement. Pupils extremely dilated, complete insensitivity both to stimulation of axillary nerve and to pinching the toes. Section of pneumogastric nerves; attack of asthma: labored breathing. Etherization: pupillary dilatation; jerky extension of head to right, sensitivity continues and is initially very high, respiration becomes frequent, with whining after each

stimulation. The left side seems more sensitive than the right. Convulsive movements cease. Animal's condition the same as before etherization. Inspiration of ether maintained for one hour; death after twelve hours.

Autopsy: Some dark ecchymoses at the inferior border of left lung inferior lobe; some emphysematous areas, otherwise the lung tissue is normal, brain more anemic than hyperemic. The blood in the right and left heart is entirely liquid.

EXPERIMENT XXV.

Strong, large dog. Tracheostomy: ether breathed for twenty minutes, with interruptions, through the opened trachea; pupils dilated; incomplete loss of sensitivity, the animal howls especially after stimulation of sphincter ani. Apparatus removed: respiration very rapid. After complete recovery, ether (2-1/2 small syringefuls) injected into trachea; pupils dilated, great excitement, loss of sensitivity, arterial blood dark, almost black. The animal recovers. Section of pneumogastric nerves. A cannula is introduced into the trachea: pronounced asphyxial attack, abundant thick mucus coughed forcefully out of trachea; danger of suffocation. Excision of part of anterior tracheal wall; the animal recovers slowly and coughs. Injection of ether (two syringes) into trachea, the animal collapses onto its side, sleeps, pupil dilates, loss of sensitivity, in ten minutes: death.

Autopsy: Both lungs hyperemic, dark areas of varying size and shape in right lung; left lung covered by greenish areas, tracheal anterior surface of reddened (streaks and blotches), bearing reddish mucus; some dark hyperemic areas on convex surface of liver. Brain hyperemic. Both sides of heart filled with dark coagulated blood, especially on right.

EXPERIMENT XXVI.

Small dog. Inspiration of ether; rapid effect with dilatation of pupils. Complete insensibility. Section of pneumogastric nerves: no asthmatic attacks. Inspiration of ether: dilated pupils, sensibility quickly lost, complete narcosis, spasms; reflex movements (contraction of sphincter ani) continue normal.

EXPERIMENT XXVII.

Strong large-sized dog. Axillary nerve exposed. Local application of ammonia solution to the nerve: marked pain; loss of sensitivity only after more prolonged action of the ammonia. The nerve remains insensitive for a shorter period than the contralateral nerve does after application of ether. Tracheostomy and inspiration of ether without effect for a few minutes. Ether injected into trachea (one syringeful): dilatation of pupils, loss of sensibility. The animal recovers. Transection of pneumogastric nerves. Ether injected: same result.

EXPERIMENT XXVIII.

Small pregnant bitch. Inspiration of ether: some automatic movements which soon cease. Cesarean operation: removal of four fetuses. Thoracic cavity of the fetuses opened: no heart beat, no pulsation of umbilical veins; no body movements, also no cerebral congestion. The bitch remained insensitive a few more minutes.

EXPERIMENT XXIX.

Small dog. Thoracic portion of spinal cord exposed. Thoracic posterior nerve root exposed and touched with forceps: contraction of neighboring muscles without the least sign of pain. Dura mater opened. Application of a sponge containing a weak solution of strychnine (strych. 1/2 gr., starch 5 gr), immediate contractures in neighboring muscles; half a minute later, signs of tetanus, particularly rigid extension of hind legs. Trismus. Inspiration of ether through opened trachea simultaneously with introduction of ether into the rectum and application of ether locally to the spinal cord. Signs of etherization: pupillary dilatation; loss of consciousness, but without appreciable effect on the convulsions except that these perhaps increase in violence with each administration of ether vapor. After half an hour the animal was still convulsing. Insensibility persisted. After transection of the spinal cord the intensity of the leg contractions seemed to diminish; new attack of spasms every time the legs were touched.

Subsequently death. Customary ecchymoses in lungs. The cavities of the stomach and thorax smelled of ether, as did the urine.

EXPERIMENT XXX.

Large dog. Spinal cord exposed: rapid narcotization by intratracheal injection of ether. Strychnine (up to one grain) applied in solution on surface of spinal cord: slight convulsions of hind legs when the animal recovers.

Autopsy: marked ecchymoses in lungs. No microscopic changes in blood corpuscles or nerves following the etherization. (Compare experiments XXXVII and XXXVIII).

IV. EXPERIMENTS

ON ETHERIZATION THROUGH THE RECTUM.

EXPERIMENT XXXI.

Ether vapor (one *gros*) mixed with ether injected into the rectum of a rabbit. Complete narcosis; motion and feeling completely abolished; eyes immobile, pupils dilated; tympanites. After sprinkling the head freely and repeatedly with cold water the animal gradually recovers.

EXPERIMENT XXXII.

Large dog. Rectum contains solid excrement. Two ounces of ether vapor introduced into rectum by means of a warm syringe. Breath smells of ether: increased salivation; sensibility impaired; narcosis not complete. The dog runs around erratically.

EXPERIMENT XXXIII.

Large dog. Two *gros* of vaporized ether in rectum. Dilatation of pupils, howls of fear, struggling, excitement without loss of sensibility; expired air smells of ether; hard feces emerge from rectum.

Autopsy: Large amount of semi-fluid excrement in large intestine; no alterations in brain.

EXPERIMENT XXXIV.

Small rabbit. Etherization through the rectum; entry of a small amount of liquid ether. Complete loss of movement and sensibility. Death in five minutes.

Autopsy: Large intestine distended by a large amount of hard feces. Dark ecchymotic areas in lungs.

EXPERIMENT XXXV.

Cat. Ether vapor injected into rectum. Within a few minutes, insensibility with tympanitic distension of lower abdomen. Apparatus removed: reflex movements of eyelids and sphincter persist for a while, but movement is lost completely a few minutes later; extreme relaxation of all muscles. The body is fully relaxed and can be bent in any direction without the slightest opposition.

The sphincter ani no longer contracts around an introduced finger; heart rate 180-220 per minute; respirations not perceptible. Sprays of cold water ammonia applied to the nose.

Touching the wound elicits reflex movements, first of the legs, next of the eyelids; respiration becomes more noticeable, the body becomes stiff, the animal ends up behaving as if drunk.

EXPERIMENT XXVI.

The same cat. Ether vapor and liquid injected into rectum. Complete insensibility, relaxation of all muscles, tympanites: death.

Autopsy: Small ecchymoses in lungs; blood liquid, bright red in left heart, dark in right heart.

EXPERIMENT XXVII.

Rabbit. Application of strychnine (about 1/8 gr.). Opisthotonus. Injections of ether vapor and liquid ether into rectum: marked tympanites; death.

Autopsy: Ecchymotic areas in lungs; blood in left heart bright red, blood in left heart dark. Brain anemic; sinuses empty of blood.

EXPERIMENT XXXVIII.

Rabbit. Etherization through the rectum: complete insensibility; loss of reflex movements, application of strychnine (1/8 gr.) to an incision. The animal recovers; but within a few minutes, convulsions and sleep. The animal has been lying there for over one hour, convulses every time it is touched. Death.

EXPERIMENT XXXIX.

Rabbit. Application of dry strychnine immediately after etherization; complete insensibility and relaxation; the animal recovers little by little. Death in 10 hours.

EXPERIMENT XL.

Dog, medium size. Abdomen opened (one inch to left of midline, at pelvis); after preliminary emptying of alimentry canal with several washes, the intestines bulge forcefully. Rectum ligated four inches above anal sphincter. The animal is very fatigued, does not cry when its nose or foot is pinched; it does withdraw the foot and move the nose. Reposition of entrails almost impossible. Injections of ether vapor into rectum. A few minutes later the breath smells of ether: insensibility, pupillary dilatation. Injection interrupted. Reposition of intestines now possible.

Autopsy. Ecchymoses in the lungs, signaling the passage of ether.

EXPERIMENT XLI.

Small dog. Lower abdomen opened very carefully; rectum ligated as close to the anal orifice as possible. Operation completed without prolapse of intestines. Ether vapor injected into rectum. Within a few minutes the breath smells of ether but not very strongly and continues to do so until the end of the experiment. Shivering; salivation and some gagging, but not insensibility, even though etherization was continued for one hour. At the end of the experiment the animal seemed as happy as could be expected considering the wound.

Autopsy: Ecchymoses in lungs, as usual. Inferior part of peritoneum inflamed. Rectum ligature 1 1/2 - 2 inches above sphincter.

EXPERIMENT XLII.

Large dog. Double ligature and transection of rectum (2 1/2 inches above sphincter ani); ether vapor introduced into rectum.

Expired air soon smells quite strongly of ether; no insensibility, not even after prolonging the etherization for half an hour. No narcotization; the animal runs about.

Autopsy: Lung changes as in the other experiments. Peritoneum inflamed. Extravasation of blood into abdominal cavity.

EXPERIMENT XLIII.

Dog, medium size. A part of the intestine one and one-half ells long tied with two ligatures, ether introduced into the cavity of the intestine between the ligatures. After a lapse of ten minutes the expired air smells strongly of ether. No insensibility, although etherization was continued for three quarters of an hour. At the end of the experiment the dog run about fairly briskly.

Autopsy: Lungs as in the other experiments: fairly large dark areas in right lung; peritonitis; marked accumulation of glary mucus on interior surface of ligated intestine, mucosal ecchymoses and erosions.

EXPERIMENT XLIV.

Rabbit. Etherization by rectum: complete insensibility. Spinal cord exposes. Etherization continued to the point of abolition of reflex responses to peripheral stimuli: convulsive response to every mechanical or galvanic stimulus to spinal cord; brain exposed and removed in layers down to medulla. Convulsive response to mechanical or galvanic stimulation of medulla: the animal continues to breathe regularly. — Thoracic cavity opened. — The cardiac movements increase in strength with galvanic stimulation of the medulla: the heart contains air bubbles smelling of ether. Dark areas in lung, similar to those usually seen after etherization. The heart continues to beat for a fairly long time and generalized muscular convulsions continue to occur after every application of galvanism.

EXPERIMENT XLV.

Small dog. A 2 - 2 1/2 inch length of intestine ligated. Ether vapor introduced into the ligated portion: Loud howls and struggles, these abate with escape of vapor from the distal end of the tied loop; after ten minutes the expired air begins to smell increasingly strongly of ether. Decrease of sensibility in twenty minutes; complete loss of sensibility only after fifty minutes. However, one can still elicit loud howls by strongly stretching the ligated intestine with ether vapor. These diminish as soon as the ether escapes. After this experiment the dog lies limp and breathes weakly. Introduction of the finger into the abdominal cavity causes howls even though the exposed axillary nerves are totally insensitive.

Autopsy: After six hours the lungs are little altered. Intestinal mucosa thickened, ecchymoses and profuse mucous secretions. The mucus forms a thick layer adherent to the mucous membrane.

(END OF EXPERIMENTS)

DISCUSSION

Two conditions are essential for etherization to produce sleep and insensibility:

1. The entry of ether vapor into the blood.
2. The contact of etherized blood with the nervous system.

I. Experience has taught me that the entry of *liquid* ether into the blood is not equivalent to the entry of ether *vapor*. I have also learned that introduction of ether vapor by inspiration, by the rectum, or directly into the circulation are not equivalent. The final result is also quite different according to whether one introduces the ether vapor through the peripheral capillary system or directs it straight to the central organ of the circulation or targets the capillary system of one of the limbs or the brain.

Liquid ether introduced into *the central end of a vein* (exp. X, XII), even one as distant from the heart as *the crural vein,* produces sudden death.

The same result ensues from introduction of ether into the peripheral end of the carotid (exp. XI).

The phenomena preceding death and the examination of the dead animal demonstrate that death is caused by sudden vaporization of the liquid, abrupt and sudden diffusion of ether vapor introduced into the blood, and rapid shrinkage of the blood corpuscles. *In the first-mentioned procedure* death is caused by a circulatory disturbance of the right side of the heart entirely similar to that of sudden entry of atmospheric air into the veins; *in the second-mentioned procedure* death is caused by sudden strong compression of the brain, principally the medulla oblongata.

A different condition develops if pure ether vapor is introduced very cautiously into the central end of a vein. The animal can then become narcotized in the same way as by inhalation of ether, although its howls of alarm inform us that the passage of venous blood (exp. XVIII, XIX) (loaded with ether vapor) through the lung greatly impedes respiration. Under such conditions sleep sets in much as after the inhalation of ether, although with different signs (cries, etc.). However, if one simultaneously introduces a little liquid ether into the circulation, death is the immediate result.

After the introduction of a mixture of ether vapor and atmospheric air into the peripheral end of the crural artery the animal does not die. It slowly becomes narcotized and presents remarkable phenomena in the hind leg (exp. XV). Its breath smells of ether; after death one notes the same changes in the pulmonary tissue as after the inspiration of either or, in general, after the injection of any other liquid into the blood stream.

Even if the ether vapor introduced into the peripheral end of the crural artery were to subdivide as minutely as possible into the capillary bed of the limb it still would not be possible to prevent a certain degree of stasis and extravasation of vapor-impregnated blood.

Such stasis and such obstructions in the capillary circulation are characterized by:

1. Constant changes in the tissue of the lung: small dark reddish and greenish spots, particularly along the back of the lung, and emphysematous bullae under the visceral pleura (see the *autopsies* of all the experiments).

2. Local swellings and ecchymoses in muscle fibers (exp. XV).

These anatomical changes also help to explain the difference in results obtained according to whether the ether vapor is introduced into the peripheral end of the crural artery or the peripheral end of the cartoid artery. In the latter case the vapor kills very rapidly because stasis of etherized blood in the cerebral capillaries leads to all the phenomena of cerebral compression and irritation.

Since passage of ether vapor through the capillaries is absolutely essential for the production of narcosis, it can of course be achieved in any one of only three ways:

1. Through the capillaries of the lung.
2. Through the peripheral capillaries.
3. Through the capillaries of the liver.

One may choose any one of these three capillary systems as the route of introduction of ether into the blood stream; that is to say, one could etherize an animal through the peripheral end of a crural artery, the central end of a crural vein, or the rectum. Our experiments show that *the signs of narcotization will never develop before the etherized blood has passed through the lung,* hence the presence of ether vapor in the expired air is *one of the surest signs of impending narcotization* and simultaneously demonstrates that *sleep and loss of the capacity to feel will supervene only as a consequence of the entry of ether into arterial blood through the capillaries of the lung.*

Thus it is the arterial blood which is the vehicle of the vapor and which communicates its sedative action to the nervous system.

No matter how large a quantity of ether vapor is intro-

duced into the blood, except for an increase in volume the physical qualities of the blood remain intact: its color is just as red as before (exp. XX, XXXVI, XXXVIII) and only becomes darkened if respiration is obstructed for some reason or other at the time of entry of the vapor into the blood (exp. XXV). Coagulation of microscopic change in the shape of the corpuscles does not occur (exp. VII).

Evidently, where physiological accounts discuss color changes and alterations in the consistency and shape of the red blood corpuscles they are alluding to the action of liquid ether and not to that of ether vapor. For whenever a few drops of the liquid gain entry into the blood stream with the vapor (during injections of the central end of a vein, for instance), prompt shrinkage of the blood corpuscles, accelerated clotting, and darkened color of the blood are observed.

Liquid ether vaporizes very rapidly at 32-35 degrees Réaumur, so it is in the form of vapor that it acts whenever it is put in contact with large surfaces such as the mucous membrane of the trachea or the ileum, for in such cases endosmosis allows only ether vapor to enter the blood stream (exp. XXVII etc.).

Accidents which occur under these circumstances differ greatly from the phenomena of etherization by vapor alone, and their explanation must be sought in the excessively rapid transformation of liquid into vapor, and the sudden violent distension of the reservoirs (the lung, the rectum) which inevitably disturbs their functions (exp. XXV, XXXIV).

Now the gentle and harmless nature of the two methods of etherization — by inspiration and by rectum — arises from two conditions:

1. The gaseous state of the ether introduced into the blood stream.

2. The extremely fine subdivided state of the vapor and its entry into the capillary network by endosmosis.

Under such conditions, as soon as the vapor has entered the arterial blood its action on the nervous system usually becomes evident immediately. Hitherto most of the experiments with ether have been effected by means of the respiratory organs, so it was necessary to determine whether such etherization depended on the tenth pair of nerves (the pneumogastric nerves). The first two experiments which I performed on animals seemed to favor this proposition. After section of the pneumogastric nerves narcotization by inspiration of ether occurred only very slowly or not at all; but repetition of the experiment (exp. XXVI, XXVII) clearly showed us that this was an accidental result of imperfect apparatus etc., and we may safely conclude from exp. XXVI that *etherization is effected just as easily after section of the pneumogastric nerves as before* and that introduction of ether vapor into the arterial system is a *purely physical phenomenon.*

II. We finally have to resolve a problem whose very nature inevitably lands us in the realm of hypotheses. We will do our best not to stray too far into the maze of speculation and to discuss only the basic question which concerns the *mechanism of action of etherized blood on the nervous system.*

The extremely prompt action of ether vapor on the cerebrospinal system, particularly during rectal etherization, might lead us to think that the power inherent in ether is transmitted not by the circulation but through the nerves; it is tempting to impute a much more rapid circulation than that of the blood to the excessively subtle fluid of the nerves. But the rapid passage of ether into the expired air (occurring within one minute) at once demonstrates that during etherization by rectum volatile substances enter the blood stream very rapidly, and the effect of ether applied directly to the nerve bundles clearly shows us that ether

vapor *does not reach the central nervous system via the nerves.*

For we observe that, after exposure and application of ether, nerve bundles temporarily lose their motor power in the absence of the slightest sign of general narcosis; the site of application in the bundle remains as sensitive to stimulation as at the start of the experiment (exp. IX).

The same thing is observed when ether is applied to the spinal cord (exp. I), the brain (exp. VI) and the olfactory bulb (exp. IV). In all these cases the action of ether remains strictly local.

In the rabbit (exp. VI) application of ether to the bared brain was followed by narcosis only when the expired air smelled of ether, implying that the ether vapor had entered the blood stream through the opened veins of the dura mater and the exposed veins of the brain.

The question arises whether etherized blood acts on the entire nervous system, that is to say equally on the central and peripheral parts of the system, or mainly on only one of these parts? At first sight the question may seem superfluous, given that the narcotic agent introduced into the blood spreads evenly to the entire body. One could, however, assume that different degrees of susceptibility to the agent exist in different parts of the nervous system. One might also hypothesize that etherized blood acts primarily on a central part of the nervous system and consecutively on other parts of this same system, etc.

It does, indeed, appear that the initial sedative action of ether vapor circulating in the arterial blood is on the brain. After the pulse accelerates and the expired air begins to smell of ether, the first signs of etherization are cerebral: dilation of the pupils, peculiar brilliance of the eyes, excite-

ment, etc. Unconsciousness develops only later, gradually, and more or less peripherally, diminished sensibility being accompanied almost simultaneously by weakening of voluntary movements. All the same, motor power continues to resist the narcotic influence of ether for some time. That is what we learned from experiment VII, in which, after etherization had produced complete loss of sensibility, mechanical stimulation of the spinal cord and nerves continued to provoke convulsions. In humans automatic movements are sometimes observed in the presence of etherization.

In view of the fact that experiments have demonstrated the power of ether to paralyze movement and feeling when applied directly to nerve bundles, one might also expect a *priori* that etherized blood will dull the sensibilities of peripheral parts before cerebral depression and insensibility become established. I have, indeed, heard of such cases. For example, I have been told of a patient who underwent excision of a small cyst while remaining entirely conscious yet without feeling any operative pain. However, I have never observed such an occurrence myself, and deem it to be a rare exception.

I therefore expect that in etherization, as with the action of other narcotics, depression of the brain will regularly precede loss of sensibility and that the two phenomena thereafter develop in parallel.

The only difference between the actions of ether vapor and other narcotic substances is that loss of sensibility by etherization requires a less profound depression than is the case with opium, tobacco, etc.

To clearly differentiate the various phenomena that accompany etherization it is absolutely essential to classify them as *different degrees:*

1. In *the first degree* the influence of etherizatoin is limited to the circulatory and respiratory organs, for *as long as* the volatile ether is mainly present in venous blood and

the arterial blood is not yet sufficiently charged with ether.

2. In *the second degree* the initial action on the brain, which is the seat of consciousness, feeling, and will, and consequently of orderly movements, becomes manifest. The spinal cord, which we may in addition suppose to have a capacity for unconscious feeling that will account for phenomena such as reflex movements, will, on the contrary, not be affected either in its motor or sensory fibers. In this degree of etherization, mechanical and galvanic stimulation still have a powerful effect on the spinal cord (exp. VII); reflex movements (exp. XXVI) and muscular tone are unimpaired although the capacity of the brain to feel consciously has long since disappeared, and even the most painful operations, such as opening the spinal canal in animals, can be performed without eliciting any sign of pain.

3. *In a higher degree* of etherization, sensibility becomes imperceptible and usually disappears together with action on the spinal cord and absence of reflex movements. One can then subject exposed nerves and the spinal cord itself to various mechanical stimuli without obtaining much response from neighboring muscles, although galvanic stimulation remains effective and the slightest contact of nervous tissue with the poles of the inducation coil immediately produces strong convulsions even in distant muscles.

4. Finally, *in the highest degree* of etherization the animal is not only devoid of feeling and movement but also betrays no effect of the spinal cord on the exhausted muscles. That is when the curious phenomenon of muscular relaxation which we observed in exp. XXXV occurs. The extremely rapid heart beat (180-210) is the only evidence that life still persists; the eye is immobile, even the strongest corneal stimulation fails to produce any eyelid response. The anal orifice is relaxed and accepts the finger without resistance, respiratory movements are imperceptible to the eye, the body is inert like a sack and can be pushed, bent,

or folded in any direction. The vital principle at such time has taken refuge in the medulla which, as is well known, governs respiration, and we can see from the red color of the arterial blood (exp. XXXVI) that respiration is still present even though invisible to the eye. Notwithstanding their profound relaxation the muscles still respond to galvanic stimulation, and what is even more remarkable, the spinal cord remains as sensitive to galvanic stimulation, and even to strong mechanical stimuli (see exp. XLIV) as before the experiment. In experiment XLIV we also find that galvanic stimulation of the medulla has a strong effect on the contraction of the heart.

Of course, the mechanism of action of etherized arterial blood remains unknown. We are not even sure whether ether vapor contained in circulating blood suppresses innervation in the same way as liquid ether applied directly to nervous tissue (exp. I, IX). And we know even less about how the local application of ether suppresses motor and sensory power in nerve fibers. Yet microscopic observation of primitive nerve fibers reveals how susceptible their envelope and contents may be (and is in practice) to compression and to the chemical action of various substances. So I think we may adopt one of the following two hypotheses to explain the action of ether vapor on the nervous system:

1. Either it is the ether vapor in the capillary system surrounding *nervous tissue that exerts a greater or lesser degree of* compression on the component fibers of the brain and nerves, partly by the force of expansion or partly by passage into the cerebrospinal fluid.

2. Or else it is the *chemical* action of ether vapor on nervous tissue.

We do not need specific evidence to realize that ether vapor readily enters the cerebrospinal fluid. Similarly, experiment shows us that when this liquid is impregnated with ether vapor it can compress the central organs of the ner-

vous system (exp. VIII). Nor is it difficult to suppose that the microscopic structure and anatomical arrangement of the cerebral capillaries render the fibers of the brain more readily and therefore more quickly compressible than those of nerves.

As for the chemical influence of ether on nervous tissue, I was very surprised to observe, with the aid of the microscope, that after the application of ether the elementary fibers of the nerves retained their double outline unchanged for a long time, and that the central part of each fiber remained transparent for longer than usual (see figs. 3 and 4) notwithstanding the large quantity of ether which I continued to pour onto the objective glass for over half an hour.

Since the fat in the medulla of nerve is dissolved by ether, the ratio of this fat to the albumen in the same tissue necessarily changes. Further, the molecules dissolved in the ether, as well as the plasma that irrigates all the animal's tissues, are freed by the prompt evaporation of the ether. These chemical changes entail a certain dryness and altered degree of heat in the nervous tissue. Howsoever that be, I think one may compare the temporary change of motor and sensory function of nervous tissue after the local application of ether to the action of cold and certain volatile substances (such as ammonia in exp. XXVII) which also nullify the motor and sensory powers of the nerve fiber.

We may suppose that the direct application of ether transforms the mutual relations of the atoms of the nerve fiber. At the etherized site, the fiber temporarily loses its excitability and ability to conduct with respect to certain stimuli but still continues to be a good conductor of galvanic stimulation.

In this regard exp. IX is very remarkable. It shows clearly that each of the three methods of stimulation, voluntary, mechanical, galvanic, acts quite differently on the

nerve fibers. For when the nerve fibers have long since ceased to conduct the will, mechanical stimulation continues to act on them strongly, and when a strong pinch with forceps of an etherized nerve trunk no longer causes pain or muscular twitching, galvanism, particularly at the crushed site, still produces very sharp pain.

Although, as noted above, we are unable to state whether blood impregnated with ether acts on nerve fibers in the same way as liquid ether, exp. VI shows quite clearly that sleep sets in only after ether vapor has entered the blood, and does not do so with direct application to the exposed brain. Perhaps treatment of the white matter of the brain with ether also evokes other phenomena, but as for me, I have not yet performed the experiment because I think its results would be very ambiguous and unclear.

Finally, we see from exp. IV that direct application to sensory nerves suppresses their specific sensitivity, since a dog became completely insensitive to stimulation of the nasal mucosa after etherization of the olfactory bulb.

Let us now summarize what we have said about the mode of action of ether, and draw from the results of our various researches the following conclusions:

1. The depressant action of ether on the nervous system takes place through the arterial blood which ether vapor enters from the pulmonary capillary system during conventional techniques of etherization.

2. By certain specific physical or chemical changes which it somehow produces in the cerebral fibres, etherized blood occasions a depression of the brain's capacity to act. This differs from the depression produced by other narcotic substances in that it dissipates more rapidly and is accompanied by more complete and more rapidly developed insensibility.

3. Our animal experiments, performed as thoroughly as possible, do not support the views of Longet and others on

the function of the anterior and posterior columns of the spinal cord. After complete loss of feeling in animals, the merest touch to the posterior columns of the cord still produces sharp twitches in the neighboring muscles.

4. Although liquid ether applied directly to nerves has a peculiar ability to inhibit their motor and sensory power, ordinary methods of etherization (through the lung and the rectum) do not suppress sensibility until the action of the brain has been more or less abolished.

5. Motor power and reflex movements are lost later, after sensibility has been completely suppressed by the etherization, but at that time —

6. The nerve fibers, although deprived of their sensory and motor power, still remain sensitive to galvanic stimulation.

ON THE METHOD OF ETHERIZATION VIA THE RECTUM

Magendie seems to have been the first to produce sleep in animals by injecting liquid ether into the rectum. It is truly surprising that surgeons have hitherto paid so little attention to his experiments or feared to introduce ether by this route yet have accorded a most enthusiastic reception to ether inhalation.

My first experiment injecting liquid ether into the rectum was performed on a large dog and was a failure: the amount was 4 ounces. It rapidly turned into vapor, forcibly dilated the lower intestinal canal and was quickly and violently discharged as flatus from the anal orifice.

I then had the idea of preventing this premature and uncontrolled effect of ether vaporized in the intestinal canal by introducing into the rectum ether in already vaporized form. A successful result conformed to my expectations, particularly if I cleaned the intestine by preliminary washing and prevented ether liquid from accidentally entering the lower intestine.

Sharp pain, which gives rise to great howls from dogs and is complained of by some patients, is a sign that some

liquid ether and not solely ether vapor has been introduced into the rectum. Flatus and colic soon become manifest, accompanied by involuntary passage of liquid stools containing much liquid ether. Herbivorous animals (rabbits) also develop marked abdominal distension and may die suddenly after the introduction of a minor quantity of liquid ether into the large intestine (exp. XXXIV).

I therefore advise that in applying this method of etherization great care should be taken to allow as little liquid ether as possible to enter the intestinal canal with the pure vapor. However, experience has taught me that this precaution is not easily carried out in practice. This is because ether vapor conducted by a rubber cannula of any great length readily cools and liquefies towards the distal end of the instrument. If the cannula is narrow and the vessel containing the ether is warmed unevenly, ether vapor formed at a distance from the exit orifice may forcibly expel ether close to the orifice. To avoid such unwelcome accidents I presently use a very suitable apparatus manufactured by Mr. Rooch, instrument maker, which comprises:

1. A metal syringe (hollow-piston clyster pump) supported either in a tin container (fig. 2) or in a glass cylinder within another glass cylinder. If the apparatus is not transparent this type of syringe is certainly the most advantageous because slight pressure on the graduated piston enables one to ascertain that the apparatus still contains enough ether vapor. In use, either apparatus must be maintained vertical to guard against the escape of liquid ether. The liquid is poured into syringe *a* or into the glass; the outside container *b* is for water at 40-50 degrees R, to convert the ether into vapor; the channel in the hollow piston of the syringe *c* serves to conduct vapor into the rubber cannula *g*. If the amount of ether turns out to be inadequate during the operation, one has to unscrew the syringe, withdraw the

piston, and pour more ether into the syringe. If, instead, one simply uses the piston to make the ether rise into the heated internal chamber, the ether instantly vaporizes and prevents any addition of liquid.

2. The second part of the apparatus is a tube of appropriate length. One might in certain circumstances make it long enough for the apparatus to be placed at some distance from the patient, even in another room. If the tube is excessively long, however, one will have to extend it with a few inches of metal tubing enclosed in a tin box. The box is essential: one pours hot water into it to encourage evaporation of ether, otherwise the vapor would cool in passing along the rubber tube and reliquefy. So, if one wants to irrigate with pure ether vapor one must be particularly careful, first to orient the apparatus vertically, and second, to keep the cannula continually bathed in hot water.

One can adapt and simplify the apparatus when a perforated chair-seat is used; then a funnel attached to the rubber tube suffices. The funnel covers and is hermetically sealed to a large container of ether. The chair must be like one used when applying leeches to the perineum. If one prefers to simply use an ordinary syringe, its parts must be very carefully made to prevent escape of ether, or complete narcotization will not succeed. That's what I was confronted with in the case of an old woman who had a gangrenous femoral hernia. A large amount of ether was consumed but the liquid escaped on all sides and the patient did not fall asleep.

Here, now, are the rules to be followed in this method of etherization:

1. Before the operation, clean the lower intestinal canal with an enema. My experiments on animals (exp. XXXII, XXXIII) and observations in human cases have shown me that this rule is absolutely essential to complete success.

In a robust peasant whom I operated on for stone I had to interrupt etherization because liquid excrement constantly entered the rubber cannula; narcotization became complete only after the rectum had been cleaned out by a motion.

In another case etherization failed because of the irritated state of the rectum; the anxious patient had developed diarrhoea the night before the operation. Finally, three other cases which I have observed have convinced me that narcotization will be difficult (requiring at least 10-20 minutes of etherization) if the lower end of the intestinal canal is not first rid of any excrement it may contain.

2. The rubber tube must be introduced into the rectum for a distance of at least 2-3 inches. Experiment XLI proved that a depth of one inch into the rectum will not effect adequate narcotization, no doubt because too much ether vapor is able to escape. With very shy people one can introduce the cannula under the bed-covers, or under the perforated chair-seat mentioned a moment ago. In fact, the operator may stay in another room and direct the etherization from there.

3. An adequate amount of liquid ether is poured either into the syringe, or, in the case of the glass apparatus, into the *inner* vessel, and hot water at 40 degrees R is introduced into the external tin or glass container.

This procedure makes the ether boil and ensures that no liquid ether, but only vapor, will emerge from the rubber tube. At this stage, and not earlier, the tip of the elastic cannula of the apparatus should be connected to the tube destined for introduction into the rectum.

The amount of ether required to produce narcotization generally does not exceed two ounces, although I have seen

instances where 2 to 4 drachms have sufficed and others where four ounces have not. Thus the dose for a particular person cannot be stated precisely, because the susceptibility to ether narcotization varies so much from one case to another. Three drachms of ether produced perfect narcosis in two minutes in a boy subjected to removal of a leg, whereas six ounces (in one quarter hour) barely sufficed to narcotize a farmer for amputation of the thigh.

By placing a hand over the sigmoid flexure of the colon one can usually detect a slight gurgling as soon as the cannula attached to the rubber tube of the apparatus enters the rectum. The lower abdomen simultaneously begins to distend, without causing any accidents displeasing to the patient unless, of course, the intestinal canal is excessively stimulated or too full of excrement or liquid ether has been inadvertently introduced. The ether vapor spreads and is discharged in the expired air (as demonstrated in animal experiments) at the same rate as if it had been introduced directly into the venous system.

Anatomical considerations suggest that during etherization *per rectum* ether vapor enters not only through the branches of the portal vein but also directly through tributaries of the inferior vena cava, although the prompt arrival of ether in the respiratory organs can also be accounted for by the very extensive communications between the portal and the inferior caval venous systems.

I have noticed in many of the patients whom I have etherized in this manner that hardly a minute elapses before a strong odor emanates from the mouth. Experiment proves that the odor is communicated to the expired air from the circulating blood, and not from the intestinal contents. After ligature of the rectum, the breath smells of ether just as quickly and just as strongly as in other experiments (exp. XLII).

Depression by etherization usually occurs more rapidly with my method than with the customary one. Most patients become narcotized in 2 or 3 minutes if there are no other obstacles. I have never seen the ordinary method produce such prompt narcotization, on the contrary, I have seen cases where depression developed only after half an hour of ether inhalation.

A very nervous French lady on whom I performed a partial excision of the perineum had breathed up to six ounces of ether in vain for half an hour, but several weeks later, when I had to make a few more incisions, she became completely narcotized by my method in two or three minutes.

Furthermore, the action of the two methods of narcotization on the organism also differs in *two* additional important respects:

1. After etherization *per anum, depression sets in without any excitement,* except occasionally if the patients are irritated by excrement contained in the intestinal canal, or by entry of liquid ether into the rectum. I have often observed the following progression in narcotization. First there is distension of the sigmoid flexure, next respiration accelerates and becomes more jerky, the expired air smells of ether, the patient complains of tenesmus which ends in the *almost involuntary expulsion* of flatus and ether; *only at this point* does the forehead become covered in sweat, the eyes close, the pulse becomes small, and sleep supervenes. In other cases narcotization develops almost imperceptibly in *the form of a quiet and profound sleep,* with the eyes open or closed and, strangely enough, usually without pupillary dilatation. The face does not always become flushed; sometimes it reddens only briefly, and often remains sallow and pale. Twice, I have seen red blotches cover the face and entire body. The conjunctiva never became very congested,

but the color and brightness of the iris as well as the expression of the eye sometimes seemed affected.

Exceptionally, a few patients had dreams, but never any true hallucinations. In one case there was a prompt occurrence of involuntary incontinence. The pulse was very rapid but small, just as in etherization by the customary method. Hitherto, the progress of the operation with my method of etherization has never been interfered with by automatic movements. Only in one case, where the rectum became irritated, have I seen the patient make any attempt to get away from the apparatus.

2. The other respect that impressed me in my method of etherization is the *complete narcotization that is usual a few moments after I remove the apparatus from the rectum.*

I have observed *remarkably rapid relaxation of the entire voluntary muscular system* in nearly all the patients whom I have etherized. In contrast, I have never observed such relaxation with the inhalational method.

The entire body becomes as relaxed and supple as a cadaver on the verge of decomposition, and can be impressed with the most varied attitudes without offering any resistance.

I have also noticed that somnolence induced *per anum* lasts relatively *much longer* than by the ordinary method and therefore requires greater care.

I excised a huge lipoma from the back of a 70-year old lady. The incision was more than two feet in circumference. The tumor was not encapsulated and consisted simply of a massive fat deposit in and continuous with the skin. The operation therefore took about twenty minutes, or longer than I had expected. Although I had only used 2 ounces of ether and the etherization lasted barely 5 minutes, she remained asleep for half an hour after the operation and so profoundly that I almost began to fear for the life of the patient. An old soldier from whose lower lip I excised a

large cancer was deeply asleep within two minutes of etherization and remained so for a full quarter hour. In another patient, who underwent amputation of the thigh, narcotization set in only after 12-14 minutes of etherization and continued throughout the operation and dressing (about 20 minutes).

The rapid and complete muscular relaxation with our method of etherization makes it far more promising in the treatment of chronic dislocations and incarcerated hernias than the inhalational method used hitherto.

Notwithstanding this profound relaxation of the voluntary muscles, the contractile property of the involuntary muscles is not abolished. In a farmer whom I operated on for stone and who was completely insensible I found the bladder so strongly contracted that I was hard put to introduce the jaws of the extractor into the posterior part. Reflex movements (contraction of sphincters, closure of the eyelids) also persisted in this patient. But in animals deeply narcotized by this method (to the third degree) such movements were lost (exp. XXXV).

As to the sequelae of our method of etherization, they are just about the same as those of the usual method. I have, however, observed in most of my patients more abundant and more liquid stools, obviously smelling strongly of ether.

According to the above, the advantages of our method of etherization could hardly be clearer and should be listed as follows:

1. The organs of respiration are unaffected and this method is not subject to the objection made, not without reason, to the inhalational method by its opponents. For although I myself have not yet seen a case where ether inspired by my method had adverse effects on the lungs, and though large quantities of liquid ether introduced directly into the trachea and bronchi of animals do not in-

flame these structures, other surgeons have published cases where inhalation of ether was followed by death from pneumonia.

2. In the application of our method, narcotization is entirely independent of the patient's will. I have already pointed out that success with the inspiratory method depends on the patient's cooperation and ability to take deep breaths. The role of the will in its success cannot be questioned whereas in *our method* it is nil and for this very reason the method is certainly to be preferred for timorous or suspicious subjects, for children, and in veterinary surgery.

3. Lastly, because etherization *per anum* usually produces somnolence and deep, peaceful sleep *without prior excitement* this method is clearly preferable to the usual inspiratory method in major and delicate operations, which is quite often marked by excitement, automatic movements, etc.

I applied my method for the first time on a soldier who had nasal polyps in both nostrils. Immediately before somnolence became complete he was still talking to me and answering my questions intelligently. Suddenly, he fell silent; his face and body broke out in red blotches, his eye became dreamy, and feeling disappeared. I had used barely half an ounce of ether and less than three minutes to put him in this state.

Somnolence developed even more rapidly in a patient with gravel in whom a renal calculus had become stuck in the ureter. The hours of excruciating pain suffered by the patient ceased as if by magic. By evening the stone had been expelled in the urine. In another case the patient, a physician, was etherized twice through the rectum and passed a big calculus next day in the urine.

Already more than thirty major operations (such as amputations, lithotomy, excision of large tumors, etc.) in which

I have applied this method have almost invariably ended in resounding success.

In the patient in whom I performed a lithotomy without his feeling the slightest pain, extraction of the stone took a long time — caused by bladder spasm and fragmentation of the stone by the pincers.

In another case, one of delivery by forceps, it was striking to note that the baby's expired air still smelled strongly of ether 20 minutes later even though it had been washed and taken to another room. Because of cephalopelvic disproportion we had to perform at least 40-50 tractions in this case, and yet the parturient, on coming to, simply couldn't believe that delivery had taken place. The uterus contracted thereafter immediately and in the usual manner. I had administered an ether vapor enema with an ordinary anatomical syringe and used about two ounces of ether. The patient was asleep in six minutes. When we began the etherization the bag of waters had already broken and the head hadn't moved for some time, the labor pains were weak, and the umbilical cord had ceased to pulsate. Nonetheless, the newborn infant was perfectly healthy.

The narcotization failed me in three cases. One where the apparatus had been poorly constructed (the rubber cannula had been dissolved by the ether and became blocked), a second in which the lower intestine had not been properly cleared of excrement, and lastly a third in which the intestinal canal had been too irritated. In two other cases narcotization was incomplete. Finally, in a hysterical lady, etherization failed by rectum as well as by inhalation.

I am convinced that the *per anum* etherization method *will entirely replace* the inspiratory method *in most cases* and that, besides operative cases, it will be appropriate for many other disorders, such as spastic affections of the intestinal canal and urinary organs.

When I first observed the remarkable state of the muscular system following rectal injection of ether vapor, in a rabbit, and when I saw that any part of the body could be given a shape incompatible with its normal stiffness, more nearly like a sack of cotton than a dead animal, the condition seemed to me to differ so much from tetanic muscular contraction that I serendipitously thought of applying my method of etherization to the treatment of tetanus. In pursuit of this objective I produced artificial tetanus in animals (exp. XXXVII, XXXVIII, XXXIX) but the results so far have been highly ambiguous.

Only in one case (exp. XXIX strychnine placed on tongue) did the tetanus cease when etherization was performed by my method, and I am unable to say whether this was merely a coincidence. In all the other cases tetanus increased in intensity either before or after etherization and in one case seemed to get ever stronger (exp. XXXVIII). The experiments on artificial tetanus do not entirely contraindicate application of etherization *per anum,* and this might yet prove very useful in spontaneous and traumatic tetanus.

From everything I have seen hitherto, I conclude that etherization *per anum* is only contraindicated with inflammation or a gonorrheal affection of the intestinal canal; the inhalational method may also be preferred on the battlefield (because of unavailability of hot water).

I believe that the differences in the development and accompaniments of depression by the two methods can be explained as follows:

With etherization *per anum* somnolence occurs much sooner, is much deeper, and lasts much longer, because the ether vapor is pure and unmixed with atmospheric air. The vapor is in contact with a greater area of mucous membrane and for a longer time, and consequently a larger quantity enters the blood stream than by the inspiratory method.

The difference in temperature of ether vapor in the two methods is also significant for the progress of the narcotization.

As a consequence of the rapid onset of somnolence there is no time for the excitement that ordinarily precedes it to develop. Hence, with our method, we see neither excitement nor venous congestion towards the head, there being no embarrassment of respiration. Although changed innervation of the lung is not a factor in the progress of somnolence (exp. XXVI), one cannot deny that entry of various substances by this route into the blood is often accompanied by various sensations. The pleasant feeling we experience with the first breath of cool air after taking a hot bath surely is due mainly to the impression it makes on the internal bronchial surface and to a different degree of distension of the alveoli. On the other hand, mechanical obstruction to respiration which has such an important effect on the oxidation of blood in the lungs also strongly affects the innervation. It is not surprising, then, that inspired air charged with ether vapor should occasionally cause accidents, such as cephalic venous congestion etc., which ordinarily do not occur with my method. Nevertheless, I do not wish to claim that entry of ether into the blood stream *per anum* cannot sometimes be associated with excitement and irritation; *however, I have never observed this in human beings*. One of my dogs did develop an access of fury (exp. XXXIII), but in this instance sleep could not develop because the large intestine was full of hard excrement.

Finally, as regards the question whether surgical etherization affects the success of an operation, in the present state of knowledge it is not easy, perhaps not even possible to devise an answer.

Nevertheless, all experience up to this point makes us feel confident that etherization does not have untoward consequences nor in the least alters the progress of the reaction to trauma etc. Furthermore, pain during an operation is a matter of the greatest importance in traumatic procedures, and expert practitioners all agree that prolonged, agonizing pain completely exhausts sensibility, just as life ebbs with the loss of blood. Is any surgeon unaware that a profound, painful assault may sometimes cause paralytic torpor and even sudden death? All known principles confirmed by our experience enable us to assert that a painless operation is less dangerous than one that inflicts pain. For we know that when pain is caused by division of organic structures and followed by the pain inseparable from the reaction of the injured tissues, the continuous suffering may produce a state of excitation of the nervous system frequently observed following major operations, especially in sensitive and excitable individuals. Hence etherization, by rendering the body insensitive to traumatic pain, will probably diminish the intensity of the nervous and febrile reaction. Time will show to what degree these conjectures will be substantiated.

Let us now summarize the results of our operations on etherized patients.

1. In 6 or 7 cases (out of a total of 50) narcotization by inhalation failed, either because of some defect in the construction of the apparatus or because the patient had not inhaled enough ether before the operation, or was handicapped by excessive aversion or fear of the ether. Out of 40 cases of etherization by my method, narcotization failed in one because the lower intestine was loaded with faeces, in another because the rubber cannula was defective, and in a third because of the irritable state of the rectum. In two other cases narcotization was more or less incomplete.

2. In none of the cases observed by me have any of the untoward consequences attributable to ether followed the operation.

3. In two cases of lithotomy (one with ether by inhalation, the other with ether by rectum), death was attributable to renal disease and to infiltration of urine into the pelvic subaponeurotic cellular tissue.

4. In all other cases, particularly following amputations, herniotomies and excisions of large tumors, the febrile reaction has been less marked. A very debilitated ten year old boy had no untoward reaction following amputation of the leg and the wound healed by first intention; of the six amputees only *one* died, of a phlebitis following amputation at the thigh.

5. Although I have not yet accumulated enough experience, particularly with my method, to reach a firm conclusion, we may reasonably hope that the administration of ether, whether by the lungs, the rectum, or the skin will eventually prove to be highly beneficial to the treatment of various internal and external affections.

Let us end by repeating once more the conclusion from our observations, that the method of etherization per rectum does have the incontestable advantage over the standard inspiratory method in that it provokes neither venous congestion of the head (inseparable from the inhalational method) nor irritation of the respiratory organs, nor excitement (ecstatic or automatic movements). It is therefore indicated principally:

a. In all very delicate, very painful, or very long major surgical operations:

Since narcosis from rectal etherization always lasts longer than narcotization by inspiration of ether vapor, it is evident that the latter will be reserved for short operations.

b. In obstetric surgery:

It is more advantageous and more convenient for women in labor (generally already predisposed to cephalic blood congestion) to be etherized *per rectum* than via the organs of respiration which, moreover, are compressed by the distended uterus.

c. In operations requiring an inactive and completely relaxed muscular system: reduction of incarcerated hernias and chronic dislocations.

d. In spastic diseases of the intestinal canal and urinary organs.

Three cases of renal colic, cured as if by magic by etherization *per rectum,* testify to its efficacity in this type of affection.

e. Lastly, in spastic conditions of voluntary muscles and animal existence. My recommendation for its use in such cases rests primarily on the extreme muscular relaxation produced by the highest degree of etherization *per rectum.*

EXPLANATION OF FIGURES

Fig. 1. MY APPARATUS FOR INHALATION OF ETHER VAPOR.

Its components are:

a. Rubber half-mask.
b. Tin funnel.
c. Two straps for attaching the mask to the head.
d. Double steel spring to shape the mask to the nose.
e. Metal tube 1 3/4 inches long, bearing:
f. Expiratory valve attached by a screw to funnel *b.*
g. Inspiratory valve.
h. Side orifice admitting air into tube when surface *h* of the tap is turned toward the opening.
i. Tap, divided by a partition into two longitudinal halves: one half, *L,* is hollow and communicates through its lower orifice *h* with the neck *n* of the vial to conduct ether vapor from the vial to tube *e.* The other half, *h,* is concavo-prismatic and closed below; when turned toward the lateral opening *h* of the tube, it allows atmospheric air to enter the tube through opening *e* and prevents passage of ether vapor from the ether vial *m.*
m. Glass or metal vial for ether.
n. Neck of bottle, fixed at right angles to tap *h* by a screw.
o. Vent tube of vial.
p. Funnel-shaped tube for introduction of ether.

Fig. 2. HOLLOW-PISTON ENEMA PUMP.

a. Syringe for liquid ether, enclosed in:
b. Tin container for hot water at 40-50 degrees R, with
c.c. Two metal circles supporting the syringe.
d. Hollow piston.

e.e. Channel in the piston, for leading the ether vapor to the rubber tube *g*.

f. Hilt of syringe, unscrewed.

g. Rubber tube to be introduced into rectum or connected by small metal tube *h* to another tube previously inserted into rectum.

i. Tap for emptying the water container.

Figures 3-7 represent nerve fibers, contrasting their normal state and their condition after application of ether, water, and acetic acid.

FIG. 3. **NERVE FIBERS IN DOG NERVE IMMEDIATELY AFTER DEATH OF ANIMAL.**

FIG. 4. **FIBERS OF SAME NERVE AFTER 30-MINUTE TREATMENT WITH LIQUID ETHER.**

FIG. 5. **FIBER FROM SAME NERVE AFTER 24-HOUR MACERATION IN ETHER.**

FIG. 6. **FIBER AFTER MACERATION IN ACETIC ACID.**

FIG. 7. *a. b. c.* **FIBERS AFTER MACERATION IN COLD WATER (15 DEGREES R) FOR 24 HOURS.**

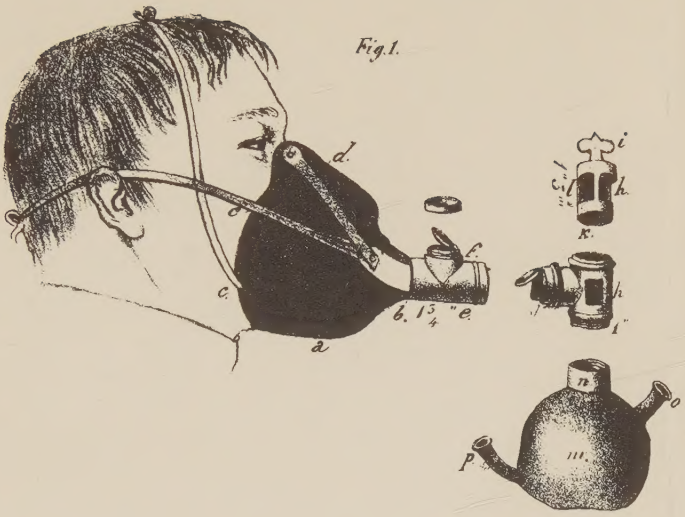


Fig. 1.
d.
f.
c.
b. 1¾" e.
a
i
h.
k.
h
l
n
o
p
m

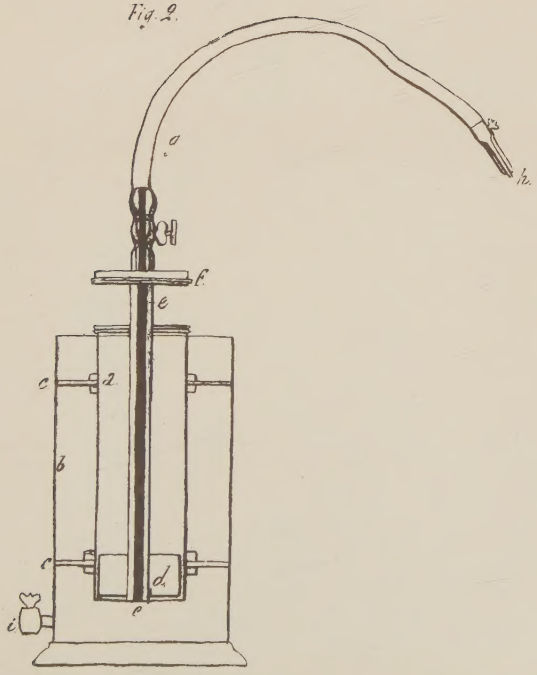


Fig. 2.
g
h.
f.
e
c
d
b
c
d.
e
i

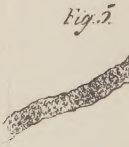


Fig. 3.

fig. 7.
a.
b.
c.

3 2044 015 342 405

WO 200.3 P671r 1992
Pirogov, Nikola˘i Ivanovich,
1810-1881.
Researches practical and

3 2044 015 342 405

The *Researches on Etherization* by Nikolai Ivanovitch Pirogoff were published in May 1847, less than six months after news of the discovery reached Europe. The Russian surgeon and humanitarian recounts his dramatic early experiences and thoughtful innovations with inhalational and rectal anesthesia. His discussion captures the torture inseparable from operations in the preanesthetic era and the miraculous relief wrought by the almost unbelievable gift from America.

The original is rare and was written in French. Dr. B. Raymond Fink's is the first complete translation into English (of the limited-edition facsimile issued by Professor Ole Secher and Janssen Pharmaceutica in 1984), and is part of the sustained endeavor by the Wood Library-Museum to publicize the proud and beneficent but too little known heritage of anesthesiology.

Published By
WOOD LIBRARY-MUSEUM OF ANESTHESIOLOGY
Park Ridge, Illinois

ISBN 0-9614932-3-2